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THE BEGINNINGS OF THE ATOMIC BOMB *

BY

SIR JAMES CHADWICK [1]

Mr. President, Ladies and Gentlemen:

I deeply regret that I am unable to be present at these Ceremonies and that I cannot convey to you in person my gratitude for the signal honour you have conferred upon me by the award of the Franklin Medal and my pleasure in it both for itself and as a new bond with my colleagues and friends in the United States.

The story of the development of the atomic bomb has been repeated so many times since the fascinating official account by Dr. H. D. Smyth that it would be tedious to tell it all once more. I wish only to draw your attention to the early work in England, for the reason that the importance of this work has been so overshadowed by the magnitude of the later scientific and technical developments as to be almost completely forgotten.

Speculations about winning useful energy from the atoms of matter had long been in the minds of scientists, but the possibility of a practicable method first appeared, in 1939, from investigations into the processes occurring in the fission of uranium, which led to the conception of a selfsustaining chain-reaction. These early ideas, which were widely current before the war, were concerned with the possibility of constructing a uranium pile, as it is now called. The first proof that this would be possible was given in December, 1940, by Halban and Kowarski, who had been working in France with Joliot and who had fled to England bringing with them their stock of heavy water. Unfortunately, their

* Talk presented at the Medal Day Meeting at The Franklin Institute, October 17, 1951. (Read by Mr. A. F. Longair, Assistant Scientific Attaché at the British Embassy, in the absence of Sir James.)

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(Note—The Franklin Institute is not responsible for the statements and opinions advanced by contributors in the JOURNAL.)

stock of heavy water was far from sufficient to enable them actually to reach the chain-reacting condition; nor was it possible, in the England of that difficult time, to set up a plant for its manufacture. For this reason, their work, though so full of promise and although we were already well aware of the potentialities of plutonium, came to a standstill and had little direct effect on the immediate course of events. As you know, the first successful pile was built by Fermi and his colleagues and put into operation in December, 1942.

It had been obvious from the beginning that a chain-reacting pile might be allowed to "run away" and release its energy explosively; it was almost equally obvious that such an explosion would be little more violent than that of an equal weight of T.N.T. and much more expensive. The possibility of the true military weapon, the atomic bomb, was, I believe, first clearly appreciated in England. We realised that uranium 235 was likely to have the properties convenient for an atomic bomb and that, if this were the case, the expense of separating it from ordinary uranium, great as this must be, would be more than repaid by the fantastic magnitude of its explosive effect. With a few colleagues, I began work, in the winter of 1940, on the problem of measuring the significant properties of uranium 235. For various reasons, it was not until the summer of 1941 that we could be sure of our facts, but we were then able to predict the size of the bomb within reasonably narrow limits and to estimate its explosive effect.

In the meantime, other workers had investigated the problem of the separation of uranium 235. They decided that the diffusion method was the most promising for continuous large scale production; laboratory experiments had been carried out, and a preliminary design of the separation machines and an estimate of cost had been made.

At this stage, the summer of 1941, we were satisfied that the project of making an atomic bomb was "practicable and likely to lead to decisive results in the war," and a full report to this effect was made to the Government, recommending immediate development on a large scale.

Work towards the utilisation of atomic energy had also been going on in the United States, and good progress had been made, more especially on the problem of the uranium pile. There was some cooperation between the committees responsible for the work in the two countries but it was not very effective; because of this, each party was rather slow to appreciate what the other was doing and why. For various reasons, the bomb project became really active in the United States in the autumn of 1941 and from that time it was pushed forward with great vigour.

There is no need to say more. We all know what a gigantic effort was made in your country, and we all appreciate what an extraordinary achievement it was in scientific and technical development and in

organization; no other project can compare with it in efficiency and rapidity of execution.

And yet it is clear enough that it could have been done even more quickly, for a great deal of time was lost in the earlier stages—in my estimate, about a whole year.

There is some interest, I think, in considering how this time was lost. First, it always takes time to grasp a new idea, to accept it, and to see its consequences, even an idea of one's own; it takes longer to convince other people, especially when the idea involves action on a big scale. Some delay from this cause is inevitable and is perhaps not without beneficial effects. The major cause of delay was the failure to achieve full cooperation between us in England and our colleagues in the United States, and the lack of personal contacts. Developments such as the atomic bomb and the aeroplane come to fruition by the ideas and efforts of a large number of men of different interests and abilities. Rapid progress can be achieved only by full cooperation, by free and frank interchange of ideas and information. When, as in the case of the atomic bomb, problems of national security are involved, cooperation must of course be subject to some restrictions; but I am quite sure, from my own experience, that these restrictions should be as few as possible. Speed of execution is itself a very valuable form of security. When time is an enemy, it is a heavy handicap to segregate groups of workers in different laboratories and to restrict too rigidly the interchange of information between them and with the outer world. As one of your scientists has so well put it—"When you lock the doors of a laboratory, you lock out more than you lock in."

Multi-Language Metal Science Newspaper.—The world's first multi-language newspaper in the field of metal science has been authorized for publication by the American Society for Metals, according to William H. Eisenman, Executive Secretary.

The Society's Board of Trustees has allocated $50,000 to finance two-year preparations toward getting out an "International Journal of Metal Science."

Eisenman revealed that two top metalists from each of 22 nations set publication policy at a special session of the First World Metallurgical Congress in Detroit, Oct. 14–19. The Detroit conclave was sponsored by the Society and was attended by more than 40,000 metal engineers, research scientists and managing executives.

The organization's Board of Trustees will be publishing agency for the new paper until a world representative Board of Governors is selected, Eisenman disclosed.

The new paper will appear in original languages of contributing writers and experts. Abstracts in English will be prepared by a staff yet to be selected, he said.

Wool's Secrets Plumbed by Radioactive Isotopes.—Radioactive isotopes, those by-products of nuclear fission which are enabling science to save lives and thus help to balance the scales tipped toward Death by the A-bomb, are being used to further man's knowledge of the fiber which also has meant life to him through the centuries—wool.

Isotopes from Britain's great atomic pile at Harwell are being transported in lead boxes each week to Torridon, Leeds, where they are used in carefully controlled experiments by the Wool Industries Research Association.

The isotopes are giving scientists new leads on the hitherto unfathomed secrets of the structure of the wool substance keratin, the physical chemistry involved in dyeing processes, and the wool fiber's baffling ability to absorb other chemical substances into its inner structure.

When a substance is radioactive its atoms are unstable, and radiation continues until Nature restores the balance. This radiation can be detected and registered by sensitive apparatus. Since a radioactive isotope behaves chemically exactly the same as its normal brother, it can be introduced into substances in small quantities as a "tracer" so that observers may follow its path.

British textile manufacturers who thought they saw in radioactivity a means of overcoming the problem of static electricity in textile handling have been disappointed, however. The Torridon scientists have warned them that use of a radioactive substance in making textiles which would be handled later by many individuals would be highly perilous, and that the risk of contaminating machinery would require careful precautions to safeguard operators' health.

Tweezers for Handling Ball Bearings.—The Baker Company of Maplewood, Maine announces new convenient tools for handling instrument ball bearings during inspection, cleaning and relubrication operations.

These new tools are essentially special tweezers for use on bearings having bores from $\frac{3}{32}$ to $\frac{1}{4}$ inch, and can be furnished in two models—one for gripping the bearing by the inside race and the other for the outer race. Their use will help avoid the corrosive effects of finger handling of bearings.

CENTENARY OF THE FOUCAULT PENDULUM

BY

THOMAS COULSON [1]

In the issue of the JOURNAL OF THE FRANKLIN INSTITUTE for May, 1851, appeared a translation of the report in *Comptes Rendus* of Foucault's success in demonstrating the rotation of the earth. In view of the fact that this report appeared one hundred years ago it is fitting that some comment be made upon one of the essential conquests of mechanics in the journal which announced it to the American people.

From the earliest times the rising and the setting of the sun, the moon, and the stars were explained by supposing the entire universe to revolve daily around the earth. About four hundred years ago a neglected theory, first advanced in reasonable form by Aristarchus of Samos in the sixth century B.C., was revived by astronomers. This was to the effect that the phenomena of the motion of celestial bodies must actually be attributed to the daily rotation of the earth. The theory came into conflict with centuries of teaching in both theological and scientific fields, but it was finally put on a logical basis by Copernicus in 1543.

One of the ways in which it was sought to decide the controversy was to devise a crucial experiment which would demonstrate beyond all doubt that the earth did or did not rotate. Direct experimental proof of the diurnal rotation of the earth, producing alternate day and night, was disconcertingly hard to secure, because until late in the seventeenth century the principles of mechanism were still under dispute. However, the natural philosophers, realizing perhaps the handicap under which they worked and the inadequacy of their knowledge, began to theorize upon the problems. Suppose the earth did rotate, what effects could be observed on its surface? One of the answers to this question was that the rotation of the earth would have an apparent effect upon the line of descent of a freely falling body, say a stone dropped from the top of a tower. Even this produced dispute. Some philosophers argued that the stone would lag behind the eastward spinning earth and would fall to the westward of the tower's base. Others held that the eastward motion of the earth was inherent in the falling body, which would show no deviation from the horizontal. Finally, Newton furnished reasons for expecting an eastern deflection. Subsequent experiments have tended to support his conclusions but no satisfactory practical proof could be provided because any man-made tower is of negligible height in relation to the radius of the earth.

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A second possibility presented itself in the flight of a projectile discharged in a northerly or southerly direction. If the earth rotated, the projectile should, in general, appear to be deflected to one side or other of the target at which it was aimed. Since the eastward speed of the earth must progressively diminish from the equator to the pole, it follows that the projectile fired northward in our latitudes must gain on the corresponding motion of the target and show a deflection toward the east. If fired in a southerly direction it must lag behind the target and show a westerly deflection. This was another ideal which could not become a practical test with the weapons available to early experimenters. The result that could be obtained would be imperceptible. Even today, with longer gun ranges and improved instruments, the deviation remains so slight as to be disentangled only with difficulty from unavoidable interferences.

It was left to the French physicist Foucault to devise a simple experiment by which he hoped to render visible the accumulated deviations of a projectile discharged backwards or forwards over a north-south trajectory, thus demonstrating the diurnal motion of the earth. He reported his first successful trials to the French Academy of Sciences in a paper dated February 3rd, 1851.

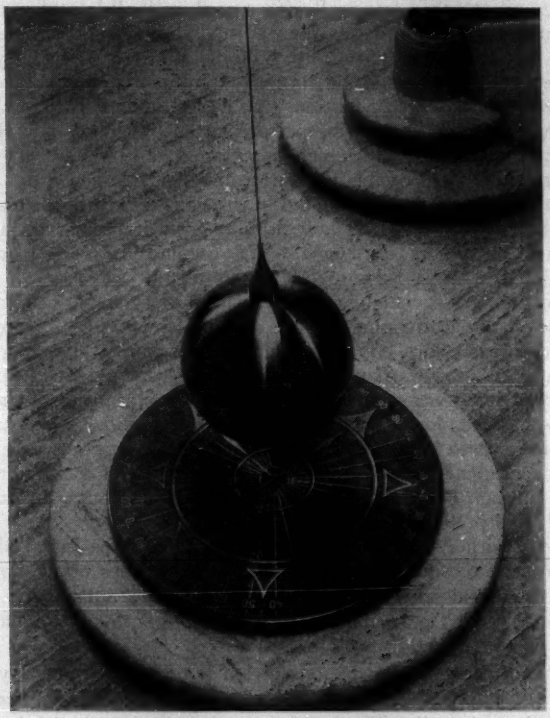
Jean-Bernard-Leon Foucault was the son of a publisher in Paris where he was born in 1819. As a child he was not robust, and his talent was not of the order which shows prominently in school work. His sole youthful distinction arose from his skill in the construction of mechanical toys. His first intention after leaving college was to train for the medical profession, but he was lured from this by the offer of an appointment at the Paris Observatory, where he found more congenial occupation. His life thereafter was devoted to the physical sciences, in which he acquired such distinction that he gained numerous honors. He is best known for his determination of the velocity of light, which he observed was higher in air than in water. This result was accepted as establishing the wave theory as opposed to the prevalent corpuscular theory of light.

However, we are concerned with the classic experiment by which Foucault demonstrated the diurnal rotation of the earth. It is not at all improbable that the idea had occurred to him through the study of Poisson's memoir read before the Academy of Sciences in November, 1837, on the effect of the earth's rotation on the trajectory of a projectile. Poisson had been able to present a calculation of that effect at the latitude of Paris. What Foucault appears to have foreseen was that the projectile could be represented by the mass of a pendulum which would have the advantage of showing the "accumulated effects and allow them to pass from the domain of theory into that of observation."

In order to accomplish this he caused a simple pendulum to swing

in a defined plane of oscillation and demonstrated that this plane showed an apparent rotation about the vertical, relative to surrounding objects.

In analyzing the phenomenon, Foucault had first to consider the behavior of the pendulum suspended vertically above a terrestrial pole, that is to say, exactly in prolongation of the earth's axis of rotation. It was clear that the oscillation would remain fixed in space owing to



The Foucault Pendulum in The Franklin Institute.

the inertia of the bob and the absence of any diversionary force. If, as the Copernican theory required, the earth rotated from west to east every twenty-four hours, then the line along which the pendulum oscillated would appear to swing around, in relation to objects on the earth, at the same rate as the earth but in the opposite direction. The problem of demonstrating this in the city of Paris was different

for, whereas the vertical retains a constant direction at the pole, elsewhere it would move through a cone in space.

Foucault's first demonstration was made in the cellar of his home with a pendulum comprising a brass bob weighing five kilograms, suspended on a wire only two meters long. The bob was provided with a sharp projection resembling the prolongation of the suspension wire. Before the pendulum was started swinging, it was drawn to one side and attached to a wall with a cord until all lateral oscillations were damped. The cord was then burned through and the pendulum allowed to begin its oscillation by the force of gravity. Strictly speaking, the pendulum should be supported from an object that will be unaffected by the earth's motion, but Foucault had learned that this condition need not be met if proper precautions were taken. His short pendulum gave him results which encouraged him to construct a larger pendulum to render possible the performance of a larger scale.

This experiment was conducted in the Salle de la Meridienne of the Paris Observatory, and Foucault profited from its height to make the pendulum 11 meters in length. The oscillations were longer and slower, but the results were manifestly improved.

Then the most spectacular demonstration was given in the Pantheon in Paris. Taking advantage of the dome, a steel wire 67 meters long was used to suspend a bob of lead encased in copper and weighing 28 kilograms. A downward projecting pin was attached to the bob and a tray containing wet sand was placed at the extremities of the oscillation so that the pin would cut a channel in the sand. The pendulum was again released by burning through the sustaining cord. The result of this experiment sufficed to show that the plane of oscillation would revolve through 360 degrees in approximately 32 hours, a result that Foucault had predicted.

Only at either pole could a perfect pendulum be installed which would appear to rotate through the full 15 degrees every hour. In practice it would pass through the 360 degrees, not in one day as measured by our clocks, but in a sidereal day, which is 23 hours, 56 minutes, and 4 seconds.

Foucault's spectacular demonstration is repeated every day in the Museum of The Franklin Institute, where the pendulum is suspended in the main stair well. The bob is a steel shell packed with lead shot, weighing 816 kilograms (1800 pounds) and the suspension is 25.9 meters (85 feet). The floor under the bob is laid out like a compass dial. The pendulum is started swinging at 10:00 A.M. each day, and observations made during hourly intervals will indicate that the plane of oscillation has rotated through 10 degrees each hour. The casual visitor may conclude that this rotation is to be attributed to the pendulum changing its direction. Actually, the pendulum's plane of

oscillation does not vary; the earth rotates, causing the floor and ceiling to move with it.

Since the ceiling must turn in sympathy with the earth's rotation, means must be adopted to install the pendulum in such a manner that it is unaffected by the association with the ceiling or roof. This is achieved by attaching the suspension wire to a hardened-steel ball which, in turn, is balanced on three other balls. This provides an almost frictionless support to the center ball from which the pendulum is suspended.

The installation of the pendulum on February 15, 1934, was attended by a parade that is probably unique in Philadelphia. Eleven men with a mounted police escort were strung out over a distance of 85 feet, each clutching the quarter-inch wire which was to be used for the pendulum suspension. The weight of the wire was no more than nine pounds, so that weight did not account for the presence of the eleven men. The reason for the elaborate escort was to be found in the desire to guard against any kinks forming in the wire that might weaken its strength.

It is interesting to note that Foucault did not permit his successful pendulum experiments to conclude his study of the earth's rotational motion. In the year following the Pantheon demonstration it occurred to him that he could duplicate this motion in a mechanical contrivance. To accomplish this he had made a massive fly-wheel pivotting freely about its center of gravity. When set in rapid motion its axis of spin indicated a fixed direction in space. Today we call this contrivance the gyroscope.

Foam-Rubber Shoe Soles.—Making foam-rubber midsoles and vulcanizing them to shoe uppers to produce a finished shoe in 12 to 18 minutes is being accomplished at the Waynesville, N. C. plant of the Wellco Shoe Corporation with the aid of General Electric Calrod* cartridge heaters.

The company "welds" a layer of foam-rubber between a soft leather outsole and the insole. By lessening shock and abrasion, the foam-rubber is said to do the same for shoes that air does for automobile tires.

The vulcanizing operation is accomplished in a specially designed machine consisting of an electrically heated last and bottom plate, and a mold. In operation, the thin outer sole is placed in the bottom mold. On this are laid felt and unvulcanized rubber strips reinforced with fiber. The shoe last is then placed on the plate, and the mold closed. Under the more than 300° F. heat furnished by the G.E. heaters, the rubber puffs to the desired thickness, and in from 12 to 18 minutes the rubber is cured, filling-out to the proper shape in the mold, and bonding itself to the upper of the shoe.

At Wellco, one operator handles 6 pairs of shoes at a time, or 12 machines. The company operates 150 such machines at the Waynesville plant to maintain a daily production of over 5000 pairs.

The G.E. heaters are rated 230-volts. Two 120-watt units are located in the last, and two 85-watt heaters are installed in the bottom plate.

According to the company, who recently furnished tough "Foam-tread"** combat boots to the Israeli army, the foam rubber with its fiber reinforcing has excellent wearing qualities because of reduced shock and abrasion.

Wellco Shoe Corp. is the American licensee for Ro-Search, Inc., under whose patents shoes are being produced in 22 foreign countries with a daily capacity of more than 100,000 pairs.

Cotton Textile Research.—A new method for speeding mercerization of cotton goods, with a resulting reduction in the hazards of processing, has been discovered by Dr. Joseph Seiberlich, of the University of New Hampshire's Engineering Experiment Station.

The new method of preparing cellulose for subsequent treatment with sodium hydroxide was patented through the Research Corporation of New York.

As a result of Dr. Seiberlich's discovery more beautiful colors may be in prospect for cotton textiles through improved methods of dyeing. Fabrics will be exposed for much shorter periods to the deteriorating elements used in the present process of mercerizing.

Economy of manufacture is also forecast through savings in time and materials.

Nor will the textile industry alone benefit by the work of the New Hampshire Engineering Experiment Station on this project, for it is said to meet the special requirements of the United States Navy for improving the insulating qualities of tape by reducing deteriorated fibers due to corrosion.

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* Reg. Trade Mark.

** Reg. Trade Mark, Wellco Shoe Corp.

CORRECTION OF SPHERICAL ERROR OF A PENDULUM

BY

V. BUSH[1] AND J. E. JACKSON[2]

Ever since precision pendulum clocks have been studied the circular error has caused difficulty. Rawlings (1)[3] states that variations of arc and circular errors are the greatest obstacles at present to improvements in the performance of fine clocks. A simple pendulum is not isochronous with changes in the arc of swing. It is difficult to hold the arc constant, although it can be done, and Loomis (2) by this and other means attained extraordinary precision. Ordinarily the arc varies, due to changes in air friction, alteration in suspension spring losses, or friction in the drive mechanism, and an elusive error results.

The equation of the simple pendulum is

$$Ml^2 \frac{d^2\theta}{dt^2} = - Mgl \sin\theta, \tag{1}$$

whereas the equation for isochronous simple harmonic motion is

$$Ml^2 \frac{d^2\theta}{dt^2} = - Mgl\theta. \tag{2}$$

Since the torque due to gravity is proportional to the sine of the angle, the period thus varies with the arc, and the motion is not truly harmonic.

Various devices have been proposed to correct the error. A very early proposal (3) was to add cheeks against which a long suspension spring would wrap, forcing the bob to move in a cycloidal path. The cheeks come out much too small and critical for practical utility. It has also been suggested that the suspension spring could be so shaped as to attain this same result, but this has not yet been worked out in practice. Adding complications to the suspension spring, which is a source of errors of its own unless it is carefully constructed in simple form, appears to be undesirable. In 1851 Loseby (4) suggested an "elastic restoring force," really a buffer spring, to correct circular error, but so far as is known a practical arrangement for doing this has not been presented.

The present paper suggests a simple method of correction which has been tried out in practice and found to operate well, and which can readily be added to existing pendulums.

[1] Carnegie Institution of Washington, Washington, D. C.

[2] Department of the Army, Washington, D. C.

[3] Boldface numbers in parentheses refer to the references appended to this paper.

From

$$\sin\theta = \theta - \frac{\theta^3}{3!} + \cdots$$

it appears that the difference in torque of the actual and ideal pendulums is, to a first approximation, a term in θ^3. If, then, a light spring is added which will produce a torque varying in this manner, correction should be obtained.

Let a tension spring be attached to a fixed point a distance b vertically below the point of suspension, as shown in Fig. 1. Let the other end be attached to the pendulum rod at a distance a below the suspension.

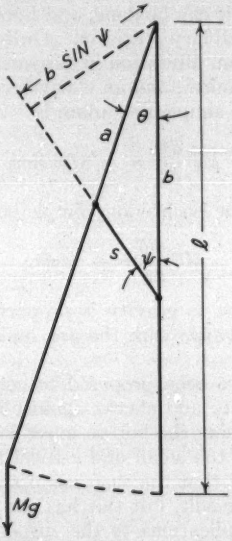

FIG. 1.

The spring length, from the figure, is then

$$s = \sqrt{b^2 + a^2 - 2ab\cos\theta}$$

and its extension beyond its minimum length is

$$s - (b - a).$$

The tension in the spring is

$$K[s - (b - a)],$$

where K is the spring constant.

Its torque is

$$T_s = Kb \sin \psi[s - (b - a)]$$
$$= Kab \sin \theta \left(1 - \frac{b - a}{s}\right).$$

With the spring in place the equation of the pendulum is

$$Ml^2 \frac{d^2\theta}{dt^2} = - Mgl \sin \theta - T_s. \tag{3}$$

In order that the right-hand side of this equation should be equal to $- Mgl\theta$ we should have

$$K = \frac{Mgl}{ab} \frac{\theta - \sin \theta}{\sin \theta} \frac{\sqrt{b^2 + a^2 - 2ab \cos \theta}}{\sqrt{b^2 + a^2 - 2ab \cos \theta} - (b - a)}. \tag{4}$$

Now if we use expansions for $\sin \theta$ and $\cos \theta$, and the binomial theorem, and retain only the principal terms, this expression reduces to

$$K = \frac{Mgl}{3} \frac{(b - a)^2}{a^2 b^2}. \tag{5}$$

This is the design expression for the spring. In general a and b should be chosen to hold ψ as well as θ small. Otherwise these distances may be chosen for convenience.

For example, assume a 14-lb. bob suspended to form a seconds pendulum, and hence on a rod approximately 40 inches from suspension to center of bob. Let the spring be fastened to a fixed point 20 inches below the suspension, and attached to the rod at a point 16 inches below the point of suspension.

Then

$$K = 0.029166 \text{ psi.}$$

This is a very light spring. In fact, if the maximum angle of swing is

$$\bar{\theta} = 0.015,$$

the torque exerted by the spring at this angle is only about 1/40,000th the torque due to the weight of the bob.

It remains to be seen whether the approximation due to dropping out higher terms above is justified. Equation 3 may be written

$$Ml^2 \frac{d^2\theta}{dt^2}$$
$$= Mgl \sin \theta - \frac{Mgl}{3} \frac{(b - a)^2}{ab} \sin \theta \left(1 - \frac{b - a}{\sqrt{b^2 + a^2 - 2ab \cos \theta}}\right). \tag{6}$$

We can write

$$(b^2 + a^2 - 2ab\cos\theta)^{\frac{1}{2}} = (b-a) + \frac{ab}{b-a}(1-\cos\theta) - \frac{a^2b^2}{2(b-a)^3}(1-\cos\theta)^2 + \cdots$$

and hence write the parenthesis in Eq. 6 as

$$\frac{ab}{(b-a)^2}(1-\cos\theta) - \frac{3}{2}\frac{a^2b^2}{(b-a)^4}(1-\cos\theta)^2 + \cdots.$$

The right-hand side of (6), using expansions for the sine and cosine, thus becomes:

$$-Mgl\left[\left(\theta - \frac{\theta^3}{3!} + \frac{\theta^5}{5!} - \cdots\right) + \frac{1}{3}\left(\theta - \frac{\theta^3}{3!} + \cdots\right)\left\{\left(\frac{\theta^2}{2!} - \frac{\theta^4}{4!} + \cdots\right) - \frac{3}{2}\frac{ab}{(b-a)^2}\left(\frac{\theta^4}{2!^2} - \frac{2\theta^6}{2!4!} + \cdots\right)\right\} + \cdots\right].$$

Gathering terms, this is

$$-Mgl\left[\theta + \theta^5\left\{\frac{1}{5!} - \frac{1}{3}\left(\frac{1}{4!} + \frac{1}{2!3!}\right) - \frac{ab}{2\cdot 2!^2(b-a)^2}\right\} - \cdots\right].$$

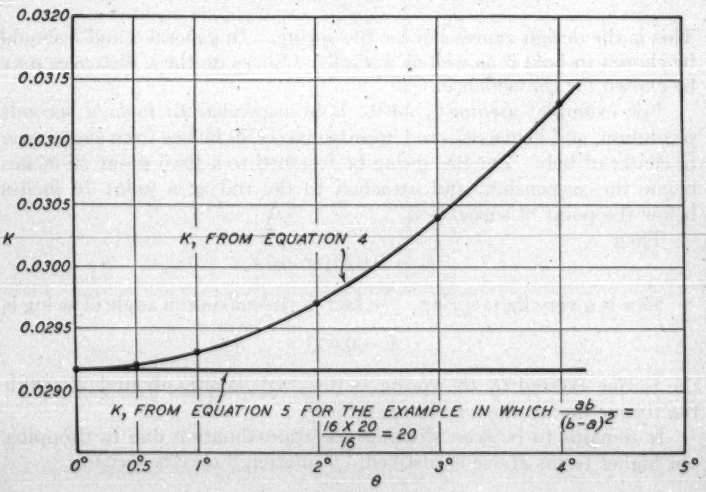

FIG. 2.

If $\frac{ab}{(b-a)^2}$ is reasonably small, then for small θ the terms decrease in size very rapidly. This is the condition for having ψ as well as θ small.

With the values given in the example above the ratio of the term in θ^5 to the term in θ at the maximum value of θ is approximately 10^{-7}. Thus, if the amplitude of swing should increase by 1 per cent, the restoring torque would depart from that necessary for isochronous motion by one part in 10^9. The approximation, with proper attention to the design constants, is thus justified for all usual conditions.

One can, of course, use the full expression to obtain K, introducing the maximum value of θ which is to be used. Figure 2 shows the values obtained from the complete and approximate expressions, for a typical example and carried out for much larger angles than would be used practically. It is to be remembered that an error made in computing K affects only the extent to which circular error is corrected.

Preliminary experiments have been made with this spring arrangement on an electrically driven pendulum without barometric correction, and no change in rate could be detected for a change in total amplitude of about one half inch. Such a change in amplitude caused more than a second a day change in rate before the spring was connected. The accuracy of measurement was to about 0.01 sec. by comparison with time signals from WWV by means of an oscilloscope.

It can be shown that slight initial tension in the spring has practically no effect on the required spring constant. This initial tension only increases the average rate of the pendulum, and can be corrected by a slight lengthening of the rod or by removing weights from the regulating pan.

A convenient construction consists in using a horizontal cantilever spring made from a flat strip of brass or steel connected to the pendulum rod by a very fine wire of length $(b - a)$. The spring constant is adjusted by lengthening or shortening the spring.

The fixed end of the spring should be mounted on a temperature compensated support, so that changes in length of the support, pendulum rod and wire will cancel out and cause no deflection of the spring with temperature changes. The use of elinvar in the spring does not seem to be necessary, as the small thermal changes in its stiffness can be taken care of in the compensating system. In any case, the correcting spring furnishes a restoring force of only about 1/40,000th of that caused by gravity on the bob, so slight errors produce only secondary effects.

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(2) ALFRED L. LOOMIS AND W. A. MARRISON, "Modern Developments in Precision Clocks," *Trans. AIEE*, Vol. 51, p. 528 (1932).
(3) CHRISTIAAN HUYGENS, *Horologium Oscillatorium*, Paris, Muguet, 1673.
(4) LORD GRIMTHORPE, *Clocks, Watches and Bells*, 1903, p. 92.

Mobile Laboratory Serves Health Program in Canada (*Inco*, Vol. 25, No. 1).—A unique mobile laboratory unit is now serving the country-wide program of Canada's Department of National Health and Welfare. Its function is to assist in special investigations in the public health field in cooperation with provincial health departments.

The vehicle is a standard bus minus passenger seats, guard rails, overhead luggage compartments and other passenger accomodation. It was built by Motor Coach Industries Limited, of Winnipeg.

Laboratory benches of Monel have been installed down each side of the unit leaving suitable aisle space. Three specially-designed incubators are installed under the table tops on the right side. A standard 4-burner stove is provided and an autoclave, gas fired, is at the rear with exhaust fans to draw off excess heat generated by the autoclave. There are two separate 110 electrical circuits, each with an individual circuit breaker and meter.

The space under the table on the left side has been designed for laboratory equipment storage, and utilizes marine-type construction on all drawers to ensure that there is no shift in position while the unit is in transit.

A deep Monel sink is installed in the center of the left table top. An ice refrigerator is directly behind the driver's seat with drainage provided through the left front wheel housing. There are 16 propane outlets and four electrical outlets.

The services for the unit are carried in the underside midships compartment. Propane storage cylinders are placed in two banks of three cylinders manifolded together so that when the gas supply in one bank is exhausted, the other bank is immediately cut in.

Servomechanisms for Missiles.—A unique method of connecting hydraulic servomechanisms with their actuating controls has been devised for a missile application through use of the Al-Fin process—a method of molecularly bonding aluminum and steel. A simple, compact and lightweight housing is produced which contains not only the connecting lines but also houses the actuating pistons so that the hydraulic cylinders become, essentially, integral parts of the unit. Passageways through the housing are thin-walled steel tubes preformed to follow their required paths.

The tubes are bonded into the aluminum with the ends blind. Admission of hydraulic fluid to the chambers which form the hydraulic cylinders is through slots milled into the tubing. Drilled holes of the proper cross section tap the lines for connection to the controls. Sealing at the control connection is made simple through use of "O" rings. Because of the bond between the walls of the tubing and the aluminum, there can be no leakage between the tapped holes, as would be the case if the tubes were merely cast into the housing.

Besides being extremely compact and light, the unit simplifies installation considerably for numerous high pressure hydraulic connections are eliminated by a single, easily mounted housing.

RECENT PROGRESS IN THE PLASTIC METHODS OF STRUCTURAL ANALYSIS

BY

P. S. SYMONDS[1] AND B. G. NEAL[2]

Part II[3]

ABSTRACT

The techniques described in Part I of this paper for the calculation of plastic failure loads under proportional loading are further exemplified by indicating solutions for a rectangular building frame, a Vierendeel girder, and a shed-type portal frame. A method for estimating deflections of a frame just as the collapse load is attained is then described, with some indications as to its reliability. More general conditions of loading than proportional loading are next discussed, and generalized load and failure concepts are defined. The theorems and techniques for determining critical shakedown loads under variable, repeated loading are then described and illustrated. The relation of the elastic-plastic shakedown analysis to the much simpler analysis for failure under single load applications is discussed.

10. FURTHER EXAMPLES OF ANALYSIS OF PLASTIC COLLAPSE

In Part I techniques were outlined for the determination of plastic failure loads on frames under "proportional loading," all individual loads being assumed to remain in constant proportion and to increase steadily to their final values. The use of these techniques may be further illustrated by the solutions to the problems indicated in Figs. 14(a), 15(a) and 16(a). Diagrams indicating convenient choices of "elementary mechanisms" of these frames are shown in the figures. The actual mode of collapse is also shown, but various trial combinations are omitted.

A problem of a rectangular building frame is shown in Fig. 14(a). This type of frame is perhaps the simplest type to treat by the methods outlined. A more complete discussion of such frames will be presented elsewhere (18).[4] In the particular case shown in Fig. 14(a) there are 22 cross-sections which need be considered as possible locations of plastic hinges in the collapse mode, as numbered in the figure. Of these sections the three under distributed loads may be placed arbitrarily at the mid-points of the respective beams. These locations are assumed as a first trial in order to determine the probable collapse mode and corresponding approximate collapse load. Their correct locations in the beam can then be determined more exactly, if desired, but the effect of this adjustment on the collapse load is usually small.

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[3] Part I appeared in this JOURNAL for November, 1951, p. 383.

[4] Boldface numbers in parentheses refer to references appended to both parts of this paper.

This frame has 12 redundant moments. Since there are 22 − 12 = 10 independent equations of equilibrium relating the 22 bending moments concerned, there are also 10 "elementary mechanisms," as explained in Sec. 9 of Part I. These include four (possibly fictitious) mechanisms corresponding to rotations at the four joints where three or more members are connected. The remaining six (true) elemen-

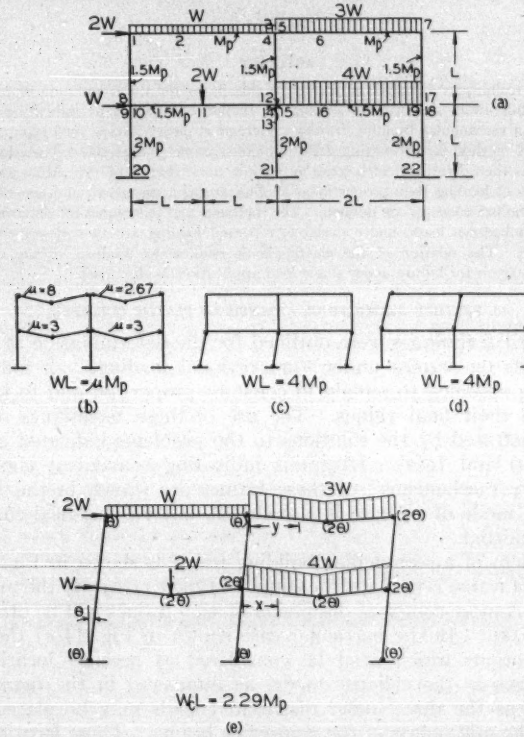

FIG. 14. (*a*) Problem of rectangular building frame under proportional loading. (*b*), (*c*), (*d*) Elementary mechanisms chosen. (*e*) Final mode of plastic collapse. Black circles indicate plastic hinge locations.

tary mechanisms are shown in Figs. 14(*b*), (*c*), (*d*). The load value given in each case is the collapse load for the mechanism shown.

The combination of elementary mechanisms requiring the smallest value of collapse load is shown in Fig. 14(*e*). This can be regarded as obtained by first combining the two "frame mechanisms" 14(*c*) and (*d*), together with suitable joint rotations, so as to leave the three

verticals straight and inclined at a common angle. This combination is found to require a smaller load value than either of the elementary frame mechanisms. This collapse load value is then further reduced by combining "beam mechanisms" of the type shown in 14(*b*) in such a way as to eliminate plastic hinges occurring at the left-hand ends of members. With the load values shown, reductions in the collapse load are obtained by using all beams except the top left-hand one in such combinations. Since no further lowering of the collapse load is produced by further combinations with the mechanism of Fig. 14(*e*), this is therefore the actual mechanism, and the corresponding collapse load is the correct one (if the plastic hinges under the distributed loads are constrained to occur at the centers of the beams concerned). The angle θ defining a small motion of the mechanism requires angles of rotation at the various hinges as shown by the numbers in parentheses. Using these, the virtual work equation for this small motion is

$$2W(2L\theta) + WL\theta + 3W(\tfrac{1}{2}L\theta) + 2W(L\theta) + 4W(\tfrac{1}{2}L\theta) = M_p[6\theta + 1.5(8\theta) + 2(3\theta)], \tag{38}$$

Thus the final (approximate) collapse load is given by

$$W_c L = \frac{24}{10.5} M_p = 2.29\, M_p. \tag{39}$$

This result is approximate because in all trials of combinations each hinge under a distributed load was taken to occur at the center of a beam. The true locations of the hinges may now be found by putting the hinges at arbitrary distances x, y from the beam end as shown in Fig. 14(*e*). Then the virtual work equation is rewritten and solved for W, and the correct values of x, y are those which minimize the expression for W so obtained. Strictly, the minimization should be performed with respect to x and y simultaneously, but in practice it suffices to consider only one variable at a time.

Thus if the hinge at section 16 is taken at x, Eq. 38 is corrected as follows

$$8.5\, WL\theta + 4W(\tfrac{1}{2}x\theta) = M_p\left[24\theta - 1.5(2\theta) + 1.5\,\frac{2x\theta}{(2L - x)}\right] \tag{40}$$

$$W = \frac{21 + \dfrac{3x}{2L - x}}{8.5L + 2x} M_p. \tag{41}$$

The minimization of W with respect to x can be carried out exactly, but again since the corrections are small it usually suffices to make a few trials of x to indicate the magnitude of the correction. The bending moments in the beam should first be examined; in the present case the moment at the right-hand end is the negative fully plastic moment, and the maximum moment under the load can be assumed to be in the left-hand half. Trial values of $x = 0.5L$, $0.7L$, and $0.9L$ yield values

$WL/M_p = 2.32$, 2.28, and 2.28, respectively. Clearly the correction due to shifting this hinge to its correct position at about $x = 0.8L$ is only about 0.01. When this process is repeated for the hinge under the distributed load $3W$ the correction in this case is found to be somewhat less than 0.01. Thus the corrected value $W_c = 2.27\ M_p/L$ of the collapse load differs by less than one per cent from that found when the hinges were assumed to be at the mid-points of the spans.

An arbitrary assumption as to the location of a hinge under a distributed load leads to an *overestimate* of the true collapse load. Another simple technique yields an *underestimate*. It can be shown that if a given distributed load is replaced by a number of concentrated forces, which are statically equivalent to it as far as the rest of the frame is concerned, then the true collapse load for the frame under this loading is less than or equal to the collapse load under the original distributed load. Thus the alternative method consists of replacing each distributed load by one or more concentrated forces. It is found that the best simple procedure is to replace a distributed load P by forces $P/2$ at one quarter of the span length from each end. Thus if the distributed load $4W$ is replaced by forces $2W$ at $x = 0.5L$ and $x = 1.5L$, while the distributed load $3W$ is replaced by forces $1.5W$ at $y = 0.5L$ and $y = 1.5L$, the virtual work equation leads to the result

$$W_c L = \frac{20.67}{9.33} M_p = 2.22\ M_p. \tag{42}$$

The advantage of this method is that it always gives a result less than the correct value, in this case by about two per cent. In general, when the suggested substitution of half the load at the two quarter-points is made, the calculated collapse load underestimates the true collapse load by amounts of the order of five per cent or less.

As another example of a frame with rectangular panels, the collapse analysis of a Vierendeel girder as shown in Fig. 15(*a*) will be indicated briefly. This is statically determinate externally. Since the loads are assumed applied at the joints, only the end cross-sections of the members need be considered as locations of plastic hinges. Thus there are 22 sections to be considered in the collapse analysis. There being 12 redundants in this frame, there are $22 - 12 = 10$ elementary mechanisms. Of these, six correspond to rotations at the six joints where three members meet. The remaining four elementary mechanisms are shown in Figs. 15(*b*), (*c*), (*d*), (*e*), with the corresponding collapse load value shown in each case. The true mode of collapse is shown in Fig. 15(*f*). Here the angle θ defines a small motion of the mechanism, and the numbers in parentheses give the relative rotations at the plastic hinges. The collapse load is computed as

$$W_c L = \frac{1.5(4)(\frac{1}{3}\theta)M_p}{5 + 3(2)(\frac{1}{3}\theta)} = \tfrac{8}{7} M_p = 1.14\ M_p. \tag{43}$$

The choice of "elementary" mechanisms is to a large extent arbitrary. Although the final mechanism (*f*) may be regarded as a combination of mechanisms (*b*) and (*e*) together with suitable joint rotations, it could equally well have been defined as an elementary mechanism, and the others derived from it by suitable combinations with other mechanisms.

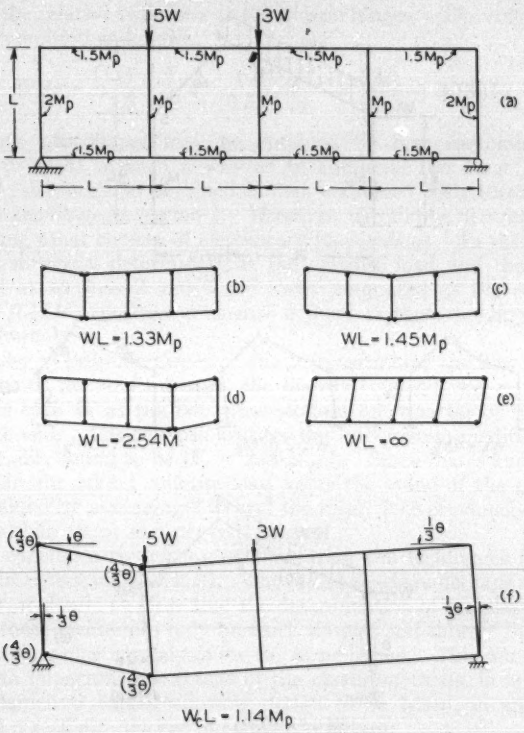

FIG. 15. (*a*) Problem of Vierendeel girder under proportional loading. (*b*), (*c*), (*d*), (*e*) Elementary mechanisms chosen. (*f*) Final mode of collapse. Black circles indicate plastic hinge locations.

In both these examples the actual collapse mode contains fewer than the number r of redundants plus one. In both cases $r = 12$, but the collapse mode 15(*e*) has 11 hinges while 15(*f*) has only 4. These are examples of what may be termed "incomplete" collapse, since fewer than $r + 1$ hinges are required. This seems to be generally the case in complex frames. The method used here of combining mechanisms to

obtain the one which requires the smallest load is particularly advantageous in these cases, since it is less easy in cases of incomplete collapse to investigate the bending moments throughout the frame, and to determine whether values of these can be found satisfying all equilibrium and plasticity conditions. On the other hand, it is comparatively easy to note all the combinations which remove plastic hinges, and to exhaust

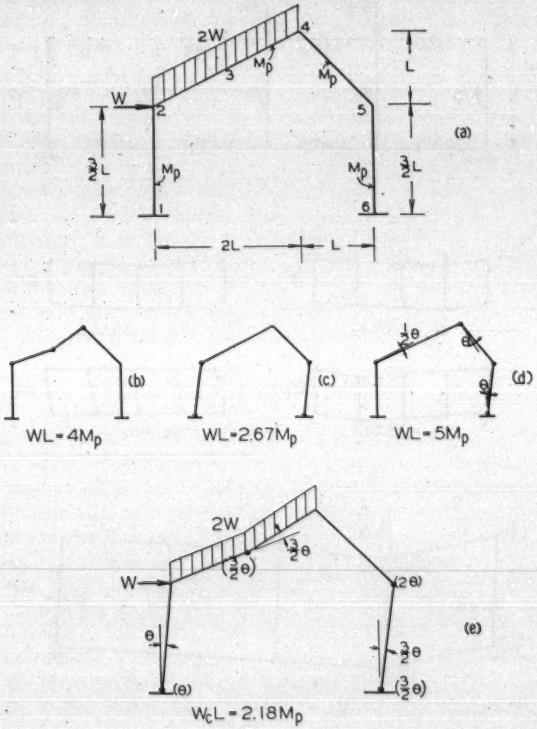

FIG. 16. (*a*) Problem of shed-type frame under proportional loading. (*b*), (*c*), (*d*) Elementary mechanisms. (*e*) Actual mode of plastic collapse.

all possibilities of advantageous combinations. However it is always desirable to check a mode of collapse believed to be correct, by investigating moments throughout the frame.

As a final example of collapse analysis, consider the shed-type portal frame shown in Fig. 16(*a*). The uniformly distributed load 2W on the sloping roof member acts vertically, while a horizontal force W acts

at the eaves level. There are six critical sections to be considered, as numbered in Fig. 16(*a*). Since the frame has three redundants, there are three elementary mechanisms, and Figs. 16(*b*), (*c*), and (*d*) show convenient choices of these. Cross-section 3 under the distributed load is first taken at the middle of the span. The correct mechanism under this assumption is shown in Fig. 16(*e*), the quantities in parentheses showing the relative rotations at the plastic hinges. The collapse load may be computed as follows:

$$W_c L = \frac{(1 + 1.5 + 2 + 1.5)M_p}{1.5 + 2 - (0.5)(1.5)} = \frac{6M_p}{2.75} = 2.18M_p. \qquad (44)$$

This mode of collapse may be obtained by first combining mode 16(*b*) with 16(*d*) in such a way as to eliminate the hinge at cross-section 4; the mode so obtained is then combined with 16(*c*) so as to eliminate the hinge at section 2. However, it could be derived in other ways, using other choices of elementary mechanisms. In this case the frame is statically determinate at the collapse load and the bending moments at sections 2 and 4 are easily computed as $M_2 = 0.27M_p$, $M_4 = -0.45M_p$ (positive moments defined as those tending to open out the frame).

In order to estimate the error due to constraining the hinge to be at the center of the roof member, the distributed load was replaced by two loads each W at the two cross-sections one quarter of the length from each end. The collapse load for the load system modified in this way is readily found to be $W_c = 2.09M_p/L$. Since this is known to be lower than the actual collapse load value the value of the coefficient 2.14 obtained by averaging 2.09 and the result 2.18 previously found is not more than about two per cent in error.

This concludes the examples illustrating the techniques for determining the plastic collapse load. The cases solved are perhaps academic. However, it should be clear that the determination of the plastic failure load by these techniques may be much simpler and shorter than would be a complete elastic analysis for the same frame. This must be considered an important advantage of the plastic methods, in addition to the fundamental one of allowing design to be based, in appropriate cases, on a realistic concept of structural failure.

11. DEFLECTION ESTIMATES

As was stated in Part I, the plastic methods are based on the concept of a failure load as a load (or narrow range of loading) at which small load increases begin to produce much larger increments of deflections than had occurred at lower load levels. In many cases it would be very desirable to be able to predict the deflections of a frame either as the failure load is just reached, or under working load values. The purpose of this Section is to describe a method for computing approxi-

mate values of deflections as the theoretical collapse load is attained. This method allows estimates of important deflections to be obtained with quickness comparable to that of the calculation of the collapse load. Although the results are likely to be less accurate than the computed values of failure *load*, for reasons to be explained, in many cases they will be satisfactory for practical purposes. Also, they are often helpful in interpreting the significance of theoretical failure loads in the plastic design methods, as will be seen.

Consider again the simple problem of a fixed-ended beam used for illustrative purposes in Part I. The force P is at $L/3$ from the left end as shown in Fig. 17(a), and in the collapse mode plastic hinges form at

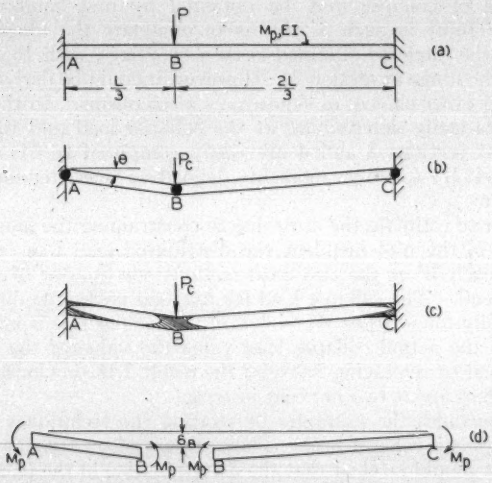

FIG. 17. (a) Problem of fixed-ended beam. (b) Collapse mechanisms, showing hypothetical hinge locations. Angle θ defines small *motion* as mechanism, not deflections. (c) Approximate deflected shape, shaded areas showing regions of plastic flow. (d) Moments at collapse load.

sections A, B, and C. The collapse load P_c can easily be found by considering the mechanism of Fig. 17(b); the virtual work equation yields

$$P_c\left(\frac{L\theta}{3}\right) = (\theta + \tfrac{1}{2}\theta + \tfrac{3}{2}\theta)M_p = 3\theta M_p \qquad (45)$$

$$P_c L = 9M_p.$$

This calculation requires only knowledge of the sections where the hinges form, and the corresponding values of fully plastic moments. It should perhaps be emphasized that the angle θ always defines an arbitrary small

motion of a beam or frame as a kinematic mechanism; it has nothing to do with the actual deflections of the structure produced by a given load.

The deflected shape of the beam as the failure load P_c is just reached is roughly as shown in Fig. 17(*c*) to an exaggerated scale. The sections *A*, *B*, *C* are actually surrounded by regions in which plastic flow has occurred in the outer fibers, as indicated by the shaded areas in the figure. In these zones where plastic flow has occurred the flexural rigidity of the beam decreases from its elastic value *EI* to zero at the theoretical hinge sections, and thus the deflections of the beam are greater than if plastic flow were localized at the hinge sections. Unfortunately the contributions of these zones to the final deflections are difficult to calculate, for the size and shape of the zones and the stresses in them depend strongly on the force and moment resultants, and on other conditions. As far as the plastic regions at the end sections are concerned, the stress distributions and displacements here may be strongly influenced by the actual manner of attachment of the beam, whereas in the failure *load* analysis it was only necessary that the supports should be capable of exerting the fully plastic moment M_p. Thus while effects of initial stresses, of imperfect constraint, of contact stresses, and other conditions are usually of negligible importance in determining the failure load, they may often have an important influence on the deflections.

It should be noted that at sections where plastic hinges are supposed to form and relative rotations assumed to occur at constant moment, the material almost certainly enters the strain-hardening range (Fig. 6, Part I). The actual strain and stress distribution at these sections in structural members are very complex but it is probable that high local strains occur, and many tests indicate that bending moments rise appreciably above the theoretical limiting values.

Since the effect of strain-hardening is to stiffen the member at a theoretical hinge, while the influence of the plastic zones surrounding the hinge sections is to increase the deflection, the two effects tend to counteract each other. Therefore a method for calculating deflections at the point of imminent collapse, which ignores both the plastic zones and the strain-hardening, may give satisfactory estimates of the deflections. Such a calculation may be very easily made, once the analysis to determine the failure load has been completed, by the method explained below. Its accuracy will be considered later. Obviously it must be used with appreciation of its underlying assumptions and limitations.

To start the calculation, in the problem of Fig. 17(*a*), we assume that the last hinge forms at a particular cross-section, for example at *C*. If this is the case, there is still an elastic "core" at *C* just before the load reaches the failure load value. Thus the tangent line at this section is still horizontal, no rotation having occurred just before the collapse load

is reached. The moments acting on the segment BC as the failure load is reached are shown in Fig. 17(d). The corresponding deflection at section B is denoted by δ_B, and angles of rotation at the ends B and C are denoted by θ_{BC} and θ_{CB}, respectively, defined as positive when the tangent line rotates clockwise. Writing the slope-deflection equation[5] for segment BC with the moments shown in Fig. 17(d) we obtain

$$\theta_{CB} = 0 = -\frac{\delta_B}{2L/3} + \frac{2L/3}{6EI}(2M_p - M_p) \tag{45}$$

$$\delta_B = \frac{2}{27}\frac{M_p L^2}{EI}. \tag{46}$$

This would be the correct value of the deflection if the hinge at C was actually the last one to form, as assumed. This is fairly obviously the case in this example, but in problems of other structures it is by no means obvious which hinge will form last, although the locations of the first hinges to form may be easy to guess. In any case, what can be done is to assume in turn that each hinge in the actual mechanism is the last to occur. This corresponds to a definite assumption either of continuity or of absence of rotation at each hinge location. On the basis of each such assumption an application of the slope-deflection equations leads to a value of the particular deflection which is sought. Thus in the present example the hinges at A and B are assumed, in turn, to be the final ones. The calculations are as follows, using the end moments as shown in Fig. 17(d):

Hinge A last:

$$\theta_{AB} = 0 = \frac{\delta_B}{L/3} + \frac{L/3}{6EI}(-2M_p + M_p) \tag{47}$$

$$\delta_B = \frac{1}{54}\frac{M_p L^2}{EI}. \tag{48}$$

[5] Useful forms of the slope-deflection equations, which may readily be derived or found in texts on theory of structures, are

$$\theta_{PQ} = \theta'_{PQ} + \frac{\delta}{l} + \frac{l}{6EI}(2M_{PQ} - M_{QP})$$

$$\theta_{QP} = \theta'_{QP} + \frac{\delta}{l} + \frac{l}{6EI}(2M_{QP} - M_{PQ}).$$

Here θ_{PQ}, θ_{QP} are the slope angles at ends P and Q, respectively, of a beam of span length l, flexural rigidity EI; θ'_{PQ} and θ'_{QP} are the end angles which the loads would produce in the absence of end moments or of displacement of one end with respect to the other; M_{PQ} and M_{QP} are moments at ends P and Q, respectively; and δ is the displacement of one end with respect to the other, defined as positive when the angle δ/l corresponds to a clockwise rotation. All slope angles are defined as positive when the rotations are clockwise, and the end moments are defined as positive when acting in the clockwise sense.

Hinge B last:

$$\theta_{BA} = \theta_{BC} \tag{49}$$

$$\frac{\delta_B}{L/3} + \frac{L/3}{6EI}(-2M_p + M_p) = -\frac{\delta_B}{2L/3} + \frac{2L/3}{6EI}(2M_p - M_p) \tag{50}$$

$$\delta_B = \frac{1}{27}\frac{M_p L^2}{EI}. \tag{51}$$

The *correct* location of the last hinge to form is that which yields the *largest* value of the deflection under consideration; in the present case the assumption that hinge C occurs last leads to the largest of the three deflection values, and the correct deflection under the load just as the collapse load is attained is therefore given by Eq. 46. (This is "correct" of course only under the simplifying assumptions made in the deflection analysis, as well as the assumptions involved in the failure load analysis.)

It is necessary to prove the statement that the correct assumption as to the last hinge to form furnishes the largest value of the deflection sought. Consider the shape of the beam or frame just as the collapse load is attained. At all the hinges in the collapse mode except the last one certain rotations of tangent lines have occurred, either with respect to the foundation or of the segment on one side of a hinge section with respect to that on the other. When one of these hinges is wrongly assumed to be the last one to occur, the actual rotation or slope discontinuity ("kink") is ignored. The assumption of absence of rotation or of a kink amounts to removing the rotation or kink. This can be visualized as done by a definite motion of the beam or frame as a kinematic mechanism in the collapse mode, since this requires (theoretically) no alteration of the loads or the bending moment distribution. The required motion of this mechanism is[6] in the reverse direction to that of the frame as it would actually collapse, and thus is such as to reduce the typical deflection under consideration. Thus the incorrect result $M_p L^2/54EI$ obtained by assuming the last hinge to occur at A may be regarded as the true value $2M_p L^2/27EI$ diminished by a certain amount due to a "backward" motion of the mechanisms. The amount of this backward motion is that required to restore the tangent line at A to the horizontal direction.

The following alternative procedure is equivalent to that detailed above, but is useful as a check (21). After assuming a particular hinge to be the last to form, and computing the value of a particular deflection, one may then easily calculate all of the angles of rotation at the remaining hinge sections. If the initial assumption was wrong it will be

[6] This is true except possibly in very special cases (20), in which rotation at a hinge in one sense is followed by rotation in the opposite sense when the loads are steadily increased. At worst this would mean that the present method would overestimate the actual deflections, and need not be worried about.

found that at one or more of the remaining hinge sections either the rotation or the slope discontinuity would be negative in sense compared to that which would actually occur as the frame deflects as a mechanism under the applied load. A mechanism motion can then be applied of an amount just sufficient to remove all these negative rotations or kinks. When the corresponding deflection is added to the value obtained from the initial (wrong) slope condition, the correct magnitude is obtained.

Either of these procedures can be applied to more complex frames to determine the approximate values of important deflections as the plastic collapse load is just attained. The practical utility of the method suggested becomes more apparent when a more difficult problem such as that of the two-span portal frame in Fig. 19 is treated. After the collapse mechanism and the failure load of this frame have been determined it would require perhaps another half-hour to compute, for example, the values of sidesway (as a typical important deflection), assuming in turn that each of the plastic hinges in the final mechanism is the last to form. The assumption which yields the largest value of the sidesway is the correct assumption, and the corresponding sidesway value may be taken as a reasonable estimate of the lateral deflection just as the failure load is reached. It should be noted that the cross-sections which are most highly stressed in the elastic range can usually be recognized by an inspection of the deformations produced by the individual loads. These cross-sections are almost certainly the locations of the first few plastic hinges to form, and thus there is no need to include these in the deflection computations. For example, in the case treated in Part I, with $H = W$, $P = 2W$, $Q = 4W$ in Fig. 19, the deformations produced by the various loads agree in sign at Sections 4, 8, and 9; thus the elastic moments at these sections are probably much larger than some of the others and it would be unnecessary to consider the plastic hinges at these locations in the deflection analysis. These considerations may shorten the work considerably.

The only practical alternative to the above method would be a step-by-step procedure in which elastic analyses are made for each loading interval in which there is a fixed number of plastic hinges. The final deflection would be the sum of the deflection increments in each of these intervals. The method described in this paper would seem to offer a considerable short-cut as compared with this procedure. As far as more refined calculations are concerned, using such methods as those described by Hrennikoff (22) or Horne (23), these are valuable for research purposes since they can be used to show effects of using realistic stress-strain diagrams and of the plastic zones, for example. However they would be much too lengthy for practical use in any but very simple structures.

The statement made above, that deflection magnitudes computed by

the method suggested in this paper are likely to be reasonable estimates, is based mainly on comparisons which have been made with measured deflections in a very complete series of tests on small-scale portal frames, recently published by Baker and Heyman (24). These comparisons are described in some detail elsewhere (20). In many cases it was found that the two opposing effects of strain-hardening and increased flexibility in the plastic zones roughly balanced each other. In other cases the computed deflections were considerably in error, some results being too high and others too low.

A few other comparisons with test results reported on various continuous beams have been made (21), with similar conclusions. The only comparison available (20) with more refined calculations is for a pin-based portal frame for which deflections were computed by Horne (23) taking into account in one case both strain-hardening and the influence of plastic zones and in the other case only the effects of plastic zones, assuming an "ideally plastic" material. In this particular case the two opposing effects cancelled each other almost exactly, and the sidesway according to the present method agreed to within a few per cent with the value computed by the most accurate method. However, these comparisons are certainly not sufficient evidence. Many more tests are needed, especially on full-scale frames with members of standard commercial steel sections and erected by ordinary fabrication processes.

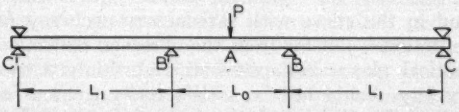

FIG. 18. Continuous beam problem investigated by Stüssi and Kollbrunner (27).

It is of interest to note that conservative estimates (larger than observed values of deflections) under *working* loads were obtained in every case used for comparison by dividing the computed deflection at the collapse load by the load factor of safety, taking this as either 2.0 or 1.75.[7]

In addition to the uses to be expected of deflection estimates in ordinary design problems, there are certain special cases in which deflection calculations are needed in order to interpret properly the meaning of the theoretical plastic failure loads. Consider the continuous beam shown in Fig. 18. The two outer spans are of equal length L_1 and are assumed to have the same M_p and EI values as the inner span, which is of length L_0 and carries a force P at its center. The collapse load P_c corresponds to formation of plastic hinges at the mid-point and ends of

[7] The load factor 2.0 is allowed by the British Standards Institution under certain conditions (25) while the value of 1.75 has been suggested by the design research team at Cambridge University, as preferable in certain cases; it has a rational basis (26).

the central span, and is given by

$$P_c = 8\frac{M_p}{L_0}.$$

This is independent of the outer span length. However, when the deflection δ_A under the load is calculated, for any L_1 and L_0, the following formula is obtained:

$$\delta_A = \frac{M_p L_0^2}{24EI}\left(1 + 4\frac{L_1}{L_0}\right)$$

This is easily derived using the condition of slope continuity at the supports B, B'; it is obvious in this case that the final hinges to form are at these cross-sections. This result is not independent of L_1, and shows, in fact, that with sufficiently large values of the ratio L_1/L_0 the central deflection would become excessive, before the collapse load is reached.

This problem was studied by Stüssi and Kollbrunner (27). They concluded that the plastic design method was inadmissible since it led to the conclusion that the failure load was independent of the length L_1, for a given central span, whereas they state that their tests showed failure loads for $L_1/L_0 = 3$, for example, to be considerably less than those for $L_1/L_0 = 0.5$. However, they do not define precisely their criterion of "failure" except to say the "deformation = ∞." The one case for which a test curve was shown in the paper was that for $L_1/L_0 = 2$, and for this case the computed plastic failure load predicts the observed bend in the curve with satisfactory accuracy (21), and the computed deflection is not far from the observed deflection magnitude at the theoretical plastic collapse load. Certainly a case for which L_1/L_0 is very large could not be satisfactorily treated in the plastic methods by the failure load analysis alone, since the deflections would probably be excessive before the failure load of the theory was reached. However, in cases like this the simple deflection analysis of the type proposed shows clearly the limitations of the load analysis by itself, and used in conjunction with the latter should lead to satisfactory designs.

12. GENERALIZED LOADING AND FAILURE CONCEPTS

The methods described in the preceding Sections were concerned with the analysis of plastic collapse under proportional loading, all the loads being increased from zero to their final values while remaining in constant proportion to each other. Actually the failure load analysis described applies to somewhat more general loading: the structure will fail by plastic collapse when the computed failure load is applied, with the individual loads in the ratios existing at the collapse load, and independently of how the individual loads are brought up to their final values at collapse, *provided collapse under some other load system does not previously occur*. This is true because the basic theorems (Sec. 7, Part I) are concerned only with a definite set of loads at or very close to their

values which produce collapse; also the geometrical factors concerned are those which exist at imminent collapse and need not be those of the original unloaded structure, although they usually can and should be taken as such. However the proviso stated, that collapse does not occur under some other load combination, is an important one conceptually, if not practially. The term "proportional loading" was used to avoid having to repeat this rather cumbersome proviso. Failure under "a single load application" would otherwise have been a preferable term to use.

These loading conditions to which the plastic collapse analysis is applicable are still rather restrictive. In many practical problems the various individual loads are more or less completely independent of each other, and each one will be applied an unspecified number of times. In order to deal with such problems the previously used concepts can be generalized. Suppose the various components of a set of loads have extreme values (upper and lower limits) with specified ratios to each other. Then the term "load" can be taken to mean a set of upper and lower limits of a system of loads, and the value of the "load" might be specified by the value of any one of these limits. A "safe load" in this sense can now be defined very generally as one such that *plastic flow ultimately ceases*, no matter how the individual loads are applied. In other words, no matter in what combinations or how many times the various loads are brought to any of their extreme limits, under a safe load the structure "shakes down"; after an initial period of limited plastic flow it arrives at a state of self-straining with residual stresses such that thereafter all further load applications are carried in an elastic manner. Conversely, a load producing failure is one such that plastic flow can be made to continue indefinitely in certain members. A critical "shakedown load" is defined as a load (in the generalized sense) such that if it were increased by an arbitrarily small amount, failure in the present sense could be made to occur. This generalizes the concept of critical failure load which was used in the analysis of problems of proportional loading.[8] As noted in Part I, failure by fatigue in the conventional sense (all members nominally elastic) must be considered independently.

Failure in the generalized sense includes failure by plastic collapse under proportional load application as a special case. Thus the value of the generalized failure load is always less than or equal to the value of any individual load or combination of loads which would cause plastic collapse in a single application. It is usually found that the shakedown load is less than the collapse load, and the main purpose of the theorems and techniques which have been developed for the determination of

[8] The term "shakedown" as applied to the plastic analysis for variable, repeated loadings is due to Prager (28). Early investigations were made by Grüning (29), H. Bleich (30) and E. Melan (31). A geometrical representation due to Prager (28) is helpful in visualizing types of problems and formulating theorems (32).

shakedown loads is to enable accurate estimates to be made of how large the difference may be in practical cases. As will be seen, the two types of analysis differ in that the shakedown analysis requires first a calculation for all critical sections of the bending moments which are induced by each of the individual loads acting alone, assuming the frame to behave completely elastically. After these calculations are made the determination of the critical load for variable repeated loading follows surprisingly closely the method for proportional loading, and is about as rapid. The need for elastic solutions corresponding to the various individual loads makes the whole analysis very much more lengthy than the collapse analysis. The relations between the two types of analysis will be considered further below.

13. SHAKEDOWN ANALYSIS

Consider for illustration the frame of Fig. 19. It is supposed that the upper and lower limits of the component loads H, P, Q are in defi-

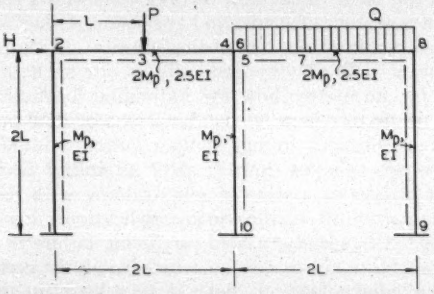

FIG. 19. Problem of variable, repeated loading.

nite ratios, but each can be varied independently of the others and applied any number of times. For illustration, the ranges of the loads will be defined as

$$0 \leq H \leq W; \qquad 0 \leq P \leq 2W; \qquad 0 \leq Q \leq 4W. \tag{52}$$

Thus the quantity W specifies the load in the generalized sense. The problem is to find the largest value of W such that the structure will shake down. This critical shakedown load W_s will be less than (or possibly equal to) the collapse load W_c which produces plastic failure under a single application either of all loads together or of any combination of them.

In addition to the assumptions detailed in Part I, each member is assumed to have a definite *elastic moment range* ΔM_y. The assumed bending moment-curvature relations are indicated by the dashed curves in Fig. 20. If the direction of loading is reversed, as at a or b,

the curve is at first a straight line at the initial elastic angle. After a definite change of moment ΔM_y, plastic flow occurs again, and with continued loading in the same direction the curvature increases indefinitely in magnitude while the moment approaches the magnitude of the fully plastic moment M_p. As a first approximation, the ratio $2M_p/\Delta M_y$ may be taken equal to the shape factor α, which was defined as M_p/M_y. This approximation is not essential and should be improved when appropriate experimental information is available concerning failure of frames under repeated loading.

The basic theorem of the shakedown analysis concerns the residual moments in the frame which are left after some plastic flow has occurred, and all external loads are then removed. A "shakedown system" of residual moments is defined as a set of moments, in equilibrium with zero values of all external loads, such that if the elastic moments cor-

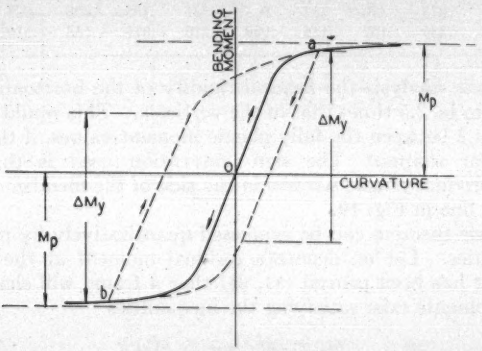

FIG. 20. Dashed lines show assumed behavior when direction of bending is reversed.

responding to any allowed combination of external loads are then superimposed, the moment in no member would be increased to the point where further plastic flow would occur. The basic theorem of the shakedown analysis states that if *any such system of residual moments exists, then the structure will shake down*, although the final residual moment system may depend on the particular loading program, that is, is not unique.

To solve a problem such as that proposed for the frame of Fig. 19, we must find the largest value of W (of Eq. 52) such that it is just possible to find a system of residual moments satisfying this definition of a shakedown system. Since elastic moments are involved, let M_i^e denote a moment at a cross-section designated by i, calculated assuming completely elastic behavior of the frame. Values of M_i^e must be computed first for unit values of each of the component loads, at

the ten sections numbered in Fig. 19. As in the collapse analysis, only these ten sections need be considered, and for the same reasons. Section 7 is assumed at first to be at the center of the beam carrying the distributed load. Values of M_i^e are then calculated for the extreme values of each of the individual loads, in terms of W and the typical length L. The maximum and minimum values of elastic bending moment corresponding to any possible combination of the three loads are then easily computed. These are denoted by $(M_i^e)_{max}$ and $(M_i^e)_{min}$, respectively. Table I shows the results of these calculations.

TABLE I.—*Elastic Moment Values.*

	M_1^e	M_2^e	M_3^e	M_4^e	M_5^e	M_6^e	M_7^e	M_8^e	M_9^e	M_{10}^e
$HL = 1$	−.339	.287	.051	−.185	.369	.185	−.051	−.287	.339	−.380
$PL = 2$	.069	−.167	.706	−.402	.162	−.258	−.117	.025	.003	−.096
$QL = 4$	.004	.033	−.156	−.344	−.216	−.560	.608	−.223	.092	.128
$(M_i^e)_{max}/WL$	.073	.320	.757	0	.531	.185	.608	.025	.434	.128
$(M_i^e)_{min}/WL$	−.339	−.167	−.156	−.949	−.216	−.818	−.168	−.510	0	.476

In the elastic analysis the flexural rigidity of the horizontal members was taken to be 2.5 times that of the verticals. This would correspond to the ratio 2 between the fully plastic moment values, if the members have similar shapes.[9] The sign convention used is that positive moments produce tensile stresses in the side of the member adjacent to the dashed line in Fig. 19.

The basic theorem can be expressed quantitatively by two systems of inequalities. Let m_i denote a residual moment at the i-th cross-section. It has been proved (33, 34) that a frame will shake down if residual moments exist satisfying the inequalities

$$m_i + (M_i^e)_{max} \leq M_{pi} \tag{53a}$$

$$m_i + (M_i^e)_{min} \geq -M_{pi}, \tag{53b}$$

provided the following inequalities are also satisfied:

$$(M_i^e)_{max} - (M_i^e)_{min} \leq \Delta M_{pi}. \tag{54}$$

The subscript i designates one of the set of cross-sections that need be considered in the analysis; in our illustrative problem $i = 1, 2, \ldots, 10$, so there are actually thirty inequalities to be satisfied.

From this point the analysis is facilitated and clarified by considering the physical effects related to the above systems of inequalities. There are two distinct kinds of failure with continuing plastic flow. In one type plastic flow is made to occur at certain sections alternately in positive and negative senses, as appropriate load combinations are repeatedly applied. This may be termed "alternating plasticity" (35).

[9] If two members are of the same material and have geometrically similar cross-sections, then if their fully plastic moments are in the ratio β, their flexural rigidities are in the ratio $(\beta)^{4/3}$.

In the other type of failure, definite amounts of plastic deformation recur *always in the same sense* as certain load sequences are repeatedly applied. Thus a frame could be made to deflect to an arbitrarily large magnitude by applying a large enough number of load cycles, but without increasing the extreme values of any of the individual loads. This type of failure is termed "incremental collapse" (38). As in the case of proportional loading the deflections of actual frames do not increase indefinitely (as the hypotheses of the theory would indicate), but are limited by effects of strain hardening and shape changes. However tests (36) show that the theoretical critical load limits have physical significance as the load limits above which a given number of cycles of certain load combinations begin to produce much larger plastic deflections than would be produced at lower load limits by the same number of cycles.

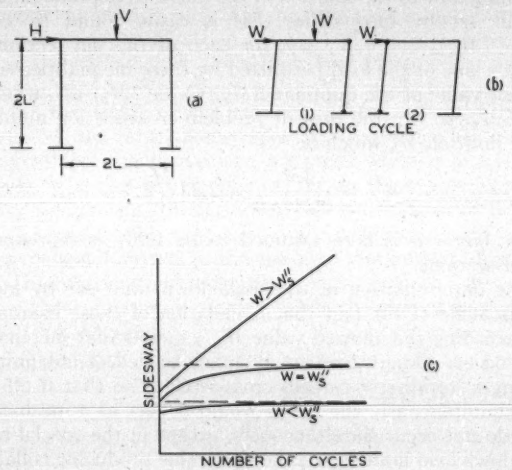

FIG. 21. Example of portal frame under cyclic loading. (*b*) shows loading cycle, consisting of loads H and V applied as in (1) followed by load H applied as in (2). (*c*) shows theoretical growth of deflections with number of load cycles.

This type of failure by incremental collapse may be made clearer by a simple example. Consider the square portal frame of Fig. 21(*a*). If both the loads shown may vary arbitrarily between zero and W, then it is found that the critical load limit above which failure by incremental collapse may occur is $W_s'' = 1.78\, M_p/L$. (Collapse under proportional loading occurs when both loads are applied simultaneously at the load $W_c = 2M_p/L$.) Now if W slightly exceeds $1.78M_p/L$, and if the cycle of loading shown in Fig. 21(*b*) is repeated, then plastic hinges form in the course of the cycle as shown. Rotations of definite amounts,

whose values depend on how much W exceeds W_s'', occur at each hinge in each cycle, and thus the sidesway increases by a definite amount in each cycle. The curves of Fig. 21(*c*) indicate how the deflections would theoretically increase with repeated applications of the cycles, for W exceeding, equal to, or less than W_s'', respectively. The indicated contrast in behavior has been verified experimentally (36).

The two systems of inequalities which express analytically the basic theorem of shakedown correspond to the two physical types of failure just discussed. If inequalities (54) are satisfied, then failure by alternating plasticity cannot occur, whereas if the other system (53) is satisfied then failure by incremental collapse cannot take place. The two systems set independent upper limits on the load, the lower of which will be the actual critical shakedown load of the problem.

Returning now to the solution of the illustrative problem, the shakedown limit set by inequalities (54) is easily found by computing $(M_i^s)_{max} - (M_i^s)_{min} = C_i W$, say, for each of the ten sections. Then the largest value of the load permitted by these inequalities is given by the *smallest* value of the quotient $\Delta M_{yi}/C_i$, or $2M_{pi}/\alpha C_i$ when ΔM_{yi} is taken as $2M_{pi}/\alpha$. In the present problem cross-section number 5 sets the upper limit on W, which is

$$W_s' = \frac{2M_p}{0.747\alpha L} = 2.23\frac{M_p}{L}. \tag{55}$$

The shape factor α is here assumed to be 1.20, as representative of standard I-sections.

For the determination of the shakedown limit set by inequalities (53) use is made of the fact that a violation of these inequalities (W slightly exceeding the allowed value W_s'') means that incremental collapse can occur. The frame can be made to deflect indefinitely, with plastic hinges forming at certain cross-sections so that if all rotations occurred simultaneously the frame would deflect as a mechanism. In fact they do not occur simultaneously, except in the special case when the shakedown load limit equals the load value producing collapse under a single application. However, the net effect of a number of repetitions of a cycle of loading is to cause a final deflection of the frame identical with that of a simple mechanism.

The analysis can thus be reduced to examining various mechanisms, as possible modes of failure by incremental collapse. The load limit W (in the present generalized sense) corresponding to any given mechanism can be readily calculated. The *actual* mechanism is that requiring the smallest value of W of all possible modes. Only for this one of the various load values corresponding to mechanisms do residual moments exist such that applications of any allowed combinations of component loads produce no further plastic flow anywhere in the structure.

As in the collapse problem, the analysis proceeds by considering first the various elementary mechanisms, and then combining them in

order to find the mechanism requiring the smallest load value. The virtual work theorem can again be used advantageously, in the form

$$\sum_i m_i \psi_i = 0. \tag{56}$$

Here m_i stands for a system of residual moments and ψ_i represents, as before, relative rotations at cross-sections where plastic hinges occur. We note that the residual moment at any section where hinge action occurs is such that the one or the other of the following equations is obeyed:

$$m_i + (M_i^e)_{\max} = M_{pi} \tag{57a}$$

or

$$m_i + (M_i^e)_{\min} = -M_{pi}. \tag{57b}$$

Strictly speaking, in order to produce incremental collapse the elastic moment would have to be such that the fully plastic moment magnitude is slightly exceeded, rather than equaled. However, since we are investigating the critical shakedown limit load the equality signs are appropriate in Eqs. 57. The choice of Eq. 57*a* or 57*b* for a given hinge is dictated by the sense of the rotation in the assumed mechanism; $+M_{pi}$ is used if the rotation corresponds to a positive bending moment (according to the sign convention adopted) while $-M_{pi}$ is used if it corresponds to a negative moment. As an illustration, consider the elementary mechanism corresponding to local collapse of the left-hand beam, with hinges at the center and both ends of the beam. The angle θ specifies the small motion of the assumed mechanism, as in Fig. 10(*c*) Part I. The rotations and moments at cross-sections 2 and 4 are negative, while those at 3 are positive. Thus the virtual work theorem in the form of Eq. 56 yields

$$(-M_p + 0.167WL)(-\theta) + (2M_p - 0.757WL)(2\theta) + (-2M_p + 0.949WL)(-\theta) = 0 \tag{57}$$

$$WL = \frac{7M_p}{2.630} = 2.66M_p. \tag{58}$$

The analysis proceeds by making simple calculations like this for each of the three elementary mechanisms, and then for combinations of these with each other and with suitable joint rotations. Guiding rules for combinations can easily be formulated, analogous to those given in Part I, Sec. 8. It is convenient to write the virtual work equations for the various mechanisms in column form as in Fig. 22, which gives a complete set of computations required to determine the shakedown load limit W_s'' for incremental collapse in the present problem. The mechanism considered in each computation is as shown above the appropriate column. (The computation for any new combination can often be made most simply by modifying the virtual work equation for a previous trial.) As in the collapse analysis, after a probable mode of incremental collapse has been obtained, the result can be corrected by

finding the true position of each hinge that was assumed, as a first approximation, to be at the center of a beam carrying a distributed load. In practice, the corrections are insignificant.

The shakedown limit corresponding to incremental collapse is here found to be $W_s'' = 2.30M_p/L$. Since this is greater than W_s'

$M_p - .167WL$
$4M_p - 1.514WL$
$2M_p - .949WL$
$7M_p - 2.630WL$
$WL \leq 2.66M_p$

$2M_p - .818WL$
$4M_p - 1.216WL$
$M_p - .510WL$
$7M_p - 2.544WL$
$WL \leq 2.75M_p$

$M_p - .339WL$
$M_p - .320WL$
$M_p - .531WL$
$M_p - .510WL$
$M_p - .434WL$
$M_p - .476WL$
$6M_p - 2.610WL$
$WL \leq 2.30M_p$

$M_p - .339WL$
$4M_p - 1.514WL$
$2M_p - .949WL$
$M_p - .531WL$
$M_p - .510WL$
$M_p - .434WL$
$M_p - .476WL$
$11M_p - 4.753WL$
$WL \leq 2.32M_p$

$M_p - .339WL$
$4M_p - 1.514WL$
$4M_p - 1.898WL$
$4M_p - 1.216WL$
$2M_p - 1.020WL$
$M_p - .434WL$
$M_p - .476WL$
$17M_p - 6.897WL$
$WL \leq 2.47M_p$

FIG. 22. Computation of load limit W for incremental collapse under variable repeated loading, frame problem of Fig. 19 with $0 \leq H \leq W$, $0 \leq P \leq 2W$, $0 \leq Q \leq 4W$.

$= 2.23M_p/L$, found from the independent criterion of absence of alternating plastic flow, the latter is the shakedown load limit W_s which is sought.

14. CONCLUSIONS

For our illustrative problem, the failure load for proportional loading was found to be $W_c = 2.75M_p/L$. The critical shakedown load limit (all loads being assumed to vary between zero and maximum values having the same ratios chosen in the problem of proportional loading) was found to be $W_s = 2.23M_p/L$. The ratio between these two loads

is

$$\frac{W_c}{W_s} = 1.23. \tag{59}$$

The value of W at which the yield stress is first reached in any member (under any combination of the loads) is denoted by W_s, and is

$$W_s = \frac{1}{0.531\alpha}\frac{M_p}{L} = 1.57\frac{M_p}{L}, \tag{60}$$

with α taken as 1.20. The ratios of the two failure loads to W_s are

$$\frac{W_c}{W_s} = 1.75, \frac{W_s}{W_s} = 1.42. \tag{61}$$

The ratio W_c/W_s is of special importance in the plastic design methods, for it indicates by how much the plastic failure load assuming proportional loading exceeds that calculated for the worst conditions of variable repeated loading. It would be very desirable if the much longer shakedown analysis (since it requires calculations for the elastic frame) can be avoided. If the ratio W_c/W_s is of the order of 1.25 or less, as in the present illustrative problem, then for practical purposes the possibility of failure under variable repeated loading can probably be disregarded. The load factors for the two loading conditions would be expected to be different (37), and the load factor for collapse under a single load application might exceed by at least 25 per cent that for failure requiring a considerable number of repetitions of certain dangerous load cycles.

Judging from preliminary results of a survey of common frame types, the difference between the two failure loads W_c and W_s is commonly well under 25 per cent in any case in which none of the important loads reverse their directions, and this will be true in the majority of practical problems. However, it should be recognized that when this cannot be assumed the shakedown load may be much less than the collapse load (often $W_s = W_c$). For example, if H in the illustrative problem varies between $-W$ and W, with P and Q as before, then $W_s = 1.50M_p/L$, $W_c = 1.42M_p/L$, and $W_c/W_s = 1.83$. In cases like these it will probably still be satisfactory to base design on the failure load assuming proportional loading, but it will be necessary to increase the load factor above the value which would be suitable if it could be assumed that none of the important loads would fluctuate many times between their extreme values. Further information from tests and from practical experience is necessary for these cases.

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LIGHT—INADEQUACY OF THE ULTRAVIOLET THEORY OF IONIZATION IN THE E-LAYER *

BY

E. F. GEORGE [1]

ABSTRACT

From the reports of the CRPL, average yearly values of h'_E, h'_{F_1}, f^o_E, and N_{F_1}, for the months of January, March, June, July, September, and December of the years 1944 to 1949 were computed and plotted against the magnetic latitude. Altogether some 25,000 individual records were averaged. Seven curves were plotted. They showed that: (1) all curves are symmetrical with respect to the magnetic equator; (2) the h'_E, h'_{F_1}, f^o_E, and the N_F, curves all swing up and down as the magnetic latitude, north and south, increases; (3) the h'_E is definitely periodic with constant period and constant amplitude; (4) the h'_E curve rises only slightly (on the average) with latitude. These results appear to be inconsistent with the ultraviolet light theory of ionization.

In Research Report No. 9, *State of the Earth's Atmosphere in the Arctic* (publication of the Geophysical Institute of the University of Alaska), some reasons were suggested for questioning the adequacy of the ultraviolet light theory of ionization of the upper atmosphere. In the preparation of that report, and in the more extensive investigations which followed, use was made of the reports of the Central Radio Propagation Laboratory, National Bureau of Standards. From these publications data were abstracted and used from the following stations: Campbell Island, Falkland Island, Christchurch, Hobart, Canberra, Watheroo, Kermadec, Brisbane, Johannesburg, Townsville, Fiji Islands, Huancayo, Cape York, Christmas Islands, Palmyra, Trinidad, Leyte P. I., Guam, San Juan, Maui, Baton Rouge, San Francisco, Washington D. C., Boston, Ottawa, St. John's, Adak, Prince Rupert, Churchill, Reykjavik, Fairbanks, and Baffin Island. These stations ranged from 52.5 degrees south geographic latitude to 70.5 degrees north, and most of the way around the earth.

On account of the meagerness of the recorded data from certain stations at certain times of the year and for certain of the factors investigated, the number of stations used in any one case ranged from 23 to 30. In all cases we used data from each station where a sufficient number of records existed to make their use worth while.

The data used covered the months of January, March, June, July, September, and December of the years 1944, 1945, 1946, 1947, 1948, and part of 1949. The months comprise the solstices, the equinoxes, and

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[1] Geophysical Institute, University of Alaska, College, Alaska.

two other months separated by half a year. The purpose was to compute as nearly as possible, a yearly average for each station. Altogether some 25,000 individual records were averaged.

During the preparation of the above-mentioned report (No. 9), the virtual height of the E-layer (h'_E) was plotted against the geographic latitude. An inspection of this curve revealed three surprising things: (1) the curve did not rise continuously (and in the higher latitudes rapidly), as might be expected from the ultraviolet light theory, but, on the average, rose very little; (2) the curve showed a queer kind of periodicity, with changing period and changing amplitude; (3) the north and south branches of the curve were not symmetrical with respect to the geographic equator. The center of symmetry appeared to be displaced southward.

After the above-mentioned report had been turned in, it was decided to plot the virtual height of the E-layer (h'_E) against the magnetic latitude. This was not easy, for accurate values of the magnetic

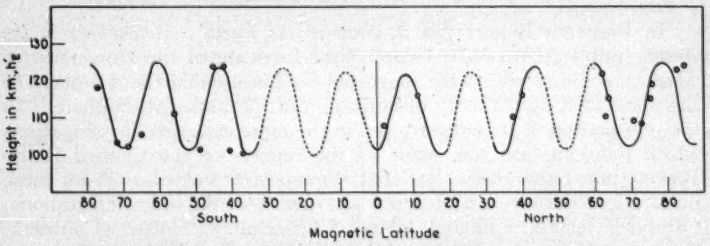


FIG. 1. Relation between virtual height of the E-layer and the magnetic latitude.

$h'_E = 112 - 11 \cos (20.6\,\theta)$, where θ = magnetic latitude in degrees.

latitudes of the various stations were not available. The best that could be done was to interpolate between the isoclinic lines on the magnetic charts. The magnetic charts available were none too accurate. Values from two different charts differed—in one case by 13.5 degrees. In no other case, however, was the disagreement more than 3 degrees, and the average variation between the two sets of values, sometimes in one direction and sometimes in the other, was 1.4 degrees.

When h'_E had been plotted against the magnetic latitude it was observed that: (1) the curve extended from 77 degrees south to 85 degrees north; (2) there was an extremely small increase in the average height, to the north and to the south; (3) the curve was periodic with a constant period and a constant amplitude; (4) the curve was accurately symmetrical with respect to the magnetic equator. The equation of the curve (shown in Fig. 1) is $h'_E = 112 - 11 \cos (20.6\,\theta)$, where θ is the magnetic latitude in degrees. The open circles, representing the

TABLE I.—*Variation of the Virtual Height of the E-Layer (h'_E) with Magnetic Latitude*

Station	Jan.	Mar.	June	July	Sept.	Dec.	Gen. Avg.	Magnetic Latitude
	h'_E in Km.							
Campbell	113	111	127	133	114	109	118	76.5 S
Christchurch	99	96	101	110	103	100	101	68.0 S
Hobart	100	104	102	106	103	104	103	73.0 S
Canberra	104	103	106	108	105	104	105	65.5 S
Kermadec	123	132	117	119	122	130	123	55.5 S
Brisbane	108	112	110	113	111	110	111	57.0 S
Johannesburg						100		62.3 S
Townsville	100	100		100	104		101	46.0 S
Fiji Islands	102	107		95	100	100	101	38.0 S
Cape York	96	102			104	97	100	34.6 S
Christmas Islands	116	114		100	100		107	5.0 N
Palmyra	107	122	113	118	112	114	114	12.0 N
Trinidad	117	114	115	117	115	116	116	43.0 N
Maui	111	112	110	108	105	112	110	39.0 N
Baton Rouge	122	120	121	121	122	124	122	62.0 N
Washington, D. C.	112	114	102	106	108	110	110	71.0 N
Ottawa	123	115	120	114	117	124	119	75.6 N
Adak	122	118	124	101	109		112	63.6 N
Prince Rupert	113		104	101		112	107	73.5 N
Churchill	124	122	124	119	124	123	123	84.3 N
Reykjavik		112	127	105			115	76.4 N
Baffin		121	111	133	129		123	84.0 N
San Francisco	117		103	110	110		110	52.8 N

individual stations, were plotted from the values given in Table I. It may be observed that, of the 23 stations plotted, not more than three are displaced from the mathematical curve by a distance greater than can be attributed to probable error—error in the magnetic latitude, error in the calibration or in the performance of the equipment, error in scaling, etc.

Encouraged by results obtained with h'_E, I decided to plot the virtual height of the F_1-layer against the magnetic latitude. The results are shown in Fig. 2. It was at once seen that the periodicity, if it existed at all, was not of the type shown in Fig. 1. The curve, however, when drawn through or very close to 21 out of 28 points plotted, does show large up-and-down swings which are quite symmetrical with respect to the magnetic equator.

In order to test this symmetry further, all the values of h'_{F_1} occurring within a certain interval of magnetic latitude (say 0 to 10, 60 to 70 degrees, etc.), were averaged and a curve plotted between these average values and the magnetic latitude. This is shown as curve A (the dot-dash curve). It may be seen that this curve, also, is very nearly symmetrical with respect to the magnetic equator.

To find out whether or not these same effects extended to the

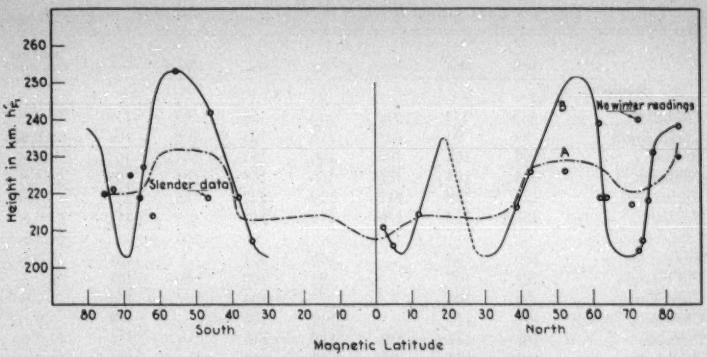


FIG. 2. Relation between virtual height of F_1-layer and magnetic latitude. Curves A and B indicate a two-fold symmetry with respect to magnetic equator.

Curve A represents average values of h'_{F_1}.
Curve B represents variation in individual values.
Hours: 8–15 inclusive.
Months: March, June, September, and December.
Years: 1944 through 1948 and part of 1949.

F_2-layer, h'_{F_2} was plotted against the magnetic latitude. No correlation could be observed. It would appear that the effects mentioned are greatest in the E-region and decrease progressively with elevation.

In Fig. 3 the critical frequency of the E-layer ($f°_E$) is plotted, from data recorded in Table II, against the magnetic latitude. In curve *A* (of Fig. 3) the values of $f°_E$ are averaged as in the case of curve *A* of Fig. 2. This curve is seen to be symmetrical about the magnetic equator. Curve *B* is not quite so definite as some of the others. Not more

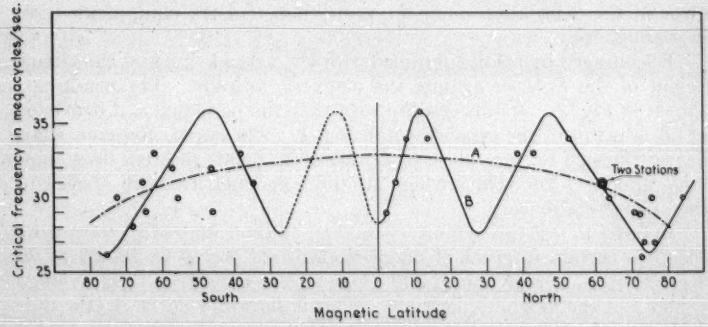


FIG. 3. Relation between the critical frequency of the E-layer and the magnetic latitude.

Curve A represents average values of $f°_E$.
Curve B represents variation of individual values.
Dotted part of curve B represents possible relation in regions where there are no stations.

TABLE II.—*Variation of the Critical Frequency of the E-Layer (f°_{E}) with Magnetic Latitude. Averages for Months of January, March, June, July, September, and December of the Years 1944–1948, and Part of 1949*

Station	Jan.	Mar.	June	July	Sept.	Dec.	Gen. Avg.	Magnetic Latitude
	f°_{E} in megacycles per second							
Campbell	2.8	3.0	2.3	2.4	2.5	2.9	2.65	76.5 S
Falkland	3.0	3.0	2.7	2.7	2.9	3.2	2.92	46.0 S
Christchurch	3.0	2.8	2.5	2.5	2.8	3.0	2.77	68.0 S
Hobart	3.2	3.0	2.7	2.8	3.0	3.1	2.97	73.0 S
Canberra	3.3	3.1	2.9	2.8	3.1	3.2	3.07	65.5 S
Watheroo	3.1	3.0	2.7	2.7	2.9	3.2	2.93	64.5 S
Kermadec	3.2	3.4	2.6	2.7	2.9	3.2	3.00	55.5 S
Brisbane	3.4	3.3	3.1	3.0	3.2	3.3	3.21	57.0 S
Johannesburg	3.4	3.3	3.1	3.2	3.4	3.4	3.30	62.3 S
Townsville	3.2	2.8	3.2	3.2	3.2	3.6	3.20	46.0 S
Fiji Islands	3.3	-	3.3	3.1	3.1	3.5	3.26	38.0 S
Cape York	3.0	3.0	3.0	3.0	3.2	3.2	3.07	34.6 S
Huancayo	3.1	3.0	2.7	2.6	3.0	3.0	2.90	2.5 N
Christmas Islands	3.0	2.8	3.2	3.2	3.2	3.0	3.07	5.0 N
Palmyra	3.5	3.5	3.6	3.6	3.6	3.6	3.57	12.0 N
Trinidad	3.2	3.3	3.4	3.4	3.4	3.2	3.32	43.0 N
Leyte	3.3	3.5	3.5	3.6	3.3	3.4	3.43	8.0 N
Guam	3.2	3.3	3.5	3.8		3.4	3.44	14.0 N
San Juan	3.2	3.5	3.8	3.5	3.4	3.3	3.45	52.8 N
Maui	3.5	3.2	3.3	3.2	3.3	3.1	3.27	39.0 N
Baton Rouge	3.0	3.1	3.2	3.2	3.1	3.0	3.10	62.0 N
San Francisco	2.9	3.1	3.2	3.2	3.1	2.9	3.07	62.0 N
Washington, D. C.	2.7	2.8	3.2	3.1	3.0	2.7	2.92	71.0 N
Boston	2.6	2.6	2.6	2.4	2.6	2.7	2.58	73.0 N
Ottawa	2.8	3.0	3.2	3.2	3.0	2.7	3.00	75.6 N
St. Johns	2.6	2.8	3.2	3.1	2.9	2.6	2.87	72.5 N
Adak	2.6	3.0	3.4	3.2	3.1	2.4	2.95	63.6 N
Prince Rupert	2.4	2.8	3.0	3.0	2.8	2.2	2.70	73.5 N
Churchill	2.8	2.9	3.2	3.2	2.9	2.8	2.97	84.3 N
Reykjavik		2.5	2.9	2.8	2.6		2.70	76.4 N

than 9 points out of 30, however, are displaced from the smooth curve by a distance greater than the probable error. This curve is quite symmetrical with respect to the magnetic equator.

The ionic concentration of the F_1-layer (N_{F_1}) was next plotted against the magnetic latitude. In curve *A* of Fig. 4 the values of N_{F_1} were averaged as for curve *A* of Figs. 2 and 3. The result is quite symmetrical about the magnetic equator. In curve *B*, 17 out of 23 points plotted fall either on or near to the smooth curve. This curve is also symmetrical about the magnetic equator.

It thus appears that the four quantities, h'_E, h'_{F_1}, f°_{E}, and N_{F_1}, represented by seven different curves, are all symmetrical with respect to the magnetic equator. To be absolutely certain of this, more sta-

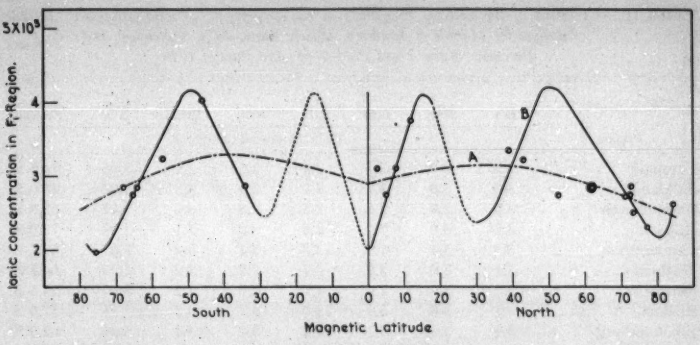


FIG. 4. Relation between ionic concentration in F_1-region and the magnetic latitude. Curves A and B indicate a two-fold symmetry with respect to the magnetic equator.

Curve A represents average values of N_{F_1}.
Curve B represents variation in individual values.
Dotted part of curve B represents possible variation where there are no stations.

tions are needed, and those stations more uniformly distributed with respect to the magnetic latitude.

COMMENTS ON THE THEORY

A. Symmetry about the Magnetic Equator

If the ionization of the air in the region of the ionosphere is due entirely (or even primarily) to ultraviolet light, there appears to be no reason why the above-mentioned effects (h'_E, h'_{F_1}, f°_E, N_{F_1}) should not be symmetrical with respect to the geographic equator instead of the magnetic equator. If, however, any considerable fraction of the ionization is due to charged particles entering our atmosphere from the outside, it might be expected that the magnetic field would exert a controlling effect. If this should be the case, then it might be possible to explain the symmetry about the magnetic equator. The fact that these effects are symmetrical about the magnetic equator and not about the geographical equator, would seem to indicate that the ionization of the E-region, in particular, is not due primarily to ultraviolet light.

B. Virtual Height versus Latitude

If ultraviolet light is responsible for the ionization of the air, say in the E-layer, then it would appear that the energy of those particular wave-lengths which are responsible for the ionization would be almost entirely used up by the time they reached the bottom of the E-layer, whether coming down vertically as at the equator or tangentially as at the poles. This, in turn, would appear to necessitate the continuous (and in the higher latitudes rather rapid) increase in the virtual height

with the latitude. Hulburt,[2] for instance, says that the virtual heights of the E-layer are 100, 120, and 140 Km. at zenith solar angles of 0, 60, and 70 to 80 degrees. Our results do not agree with those figures. The total average rise is perhaps not more than 2 or 3 Km., and the rise is in no sense continuous. Our results are difficult to explain in terms of the ultraviolet theory.

C. Periodicity

It is hard to understand how any theory of ionization thus far advanced can explain the periodicity or the up-and-down swing of the

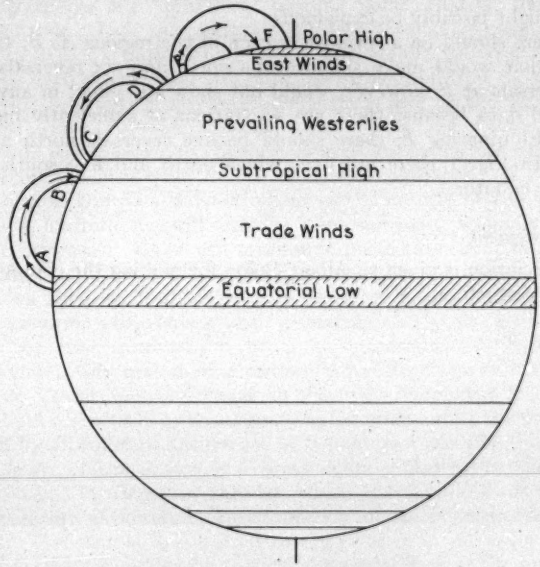


FIG. 5. Prevailing winds within the troposphere.

curves. The question that naturally presents itself is: what physical phenomenon rises and falls, or increases and decreases, with latitude, whether magnetic or geographical? One such factor, at least near the surface of the earth, is the atmospheric pressure, with the associated movements of the air. Figure 5, which is similar to figures found in almost any book on meteorology or physics, shows how the air rises in the equatorial belt of low pressure, flows north and south and comes down in the region of the sub-tropic belts of high pressure, while at the

[2] E. O. Hulburt, *Physics of the Earth*, Vol. VIII, New York, McGraw-Hill Book Co., Inc., 1939, p. 506.

sub-polar belts of low pressure it rises, moves north and south and comes down either in the regions of the polar highs or the sub-tropic highs. Now consider the region marked *A*, *B*, *C*, etc., on this figure. Suppose an ion takes part in the general movement of the air at *A*. This ion would be moving northward and upward across the earth's magnetic lines of force and would therefore spiral around these lines. At *B* an ion would be moving northward and downward and would probably spiral in the opposite direction. In each of the regions there would be a change in direction of these spiral motions.

If these large scale movements of the air should be carried on into the ionosphere, even in a reduced form, the up-and-down swings of the curves might possibly be explained.

If there should be a reversal at each of the regions *A*, *B*, *C*, *D*, *E*, and *F*, that would make six reversals north and six reversals south. The reversals at *F*, however, would not show any effect in any of the published data because there are no stations at sufficiently high latitudes. Eliminating *F*, there should be five reversals north and five south. In Fig. 1 there are five swings north and five south of the magnetic equator.

Acknowledgment

Appreciation is given to Albert Belon for making the computations in this investigation.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS *

NBS ANTIFREEZE TESTER

An easily constructed device recently developed by R. B. Rudy and J. I. Hoffman of the National Bureau of Standards makes it possible for service stations to make more reliable tests of automotive antifreeze solutions. Simple and rapid in application, the NBS Antifreeze Tester determines the "practical" freezing point, that is, the lowest temperature at which the solution will flow through a passage comparable in size to those found in an automobile radiator. Unlike the widely used hydrometer, the new device is applicable to all types of antifreeze solutions or any mixtures of them now on the market.

Almost every motorist at some time during the winter driving season finds it necessary to reassure himself regarding the protection provided by the antifreeze in his automobile radiator. If the antifreeze solution contains only ethylene glycol or one of the common alcohols, a hydrometer will usually give sufficient accuracy for all practical purposes. Even so, minimum protection temperatures as determined by different service stations on these solutions sometimes differ by as much as 30 degrees. On the other hand, if the antifreeze solution contains propylene glycol, a mixture of glycols, a mixture of alcohols, or any combination of these materials, the hydrometer becomes practically useless in determining its effectiveness. The NBS Antifreeze Tester was developed to meet the increasing need for a practical yet reasonably accurate method for determining the protection provided by all types of antifreezes in the shortest possible time.

The heart of the device is a brass cylinder having a passage 1.5 mm. (0.06 in.) in diameter, through which the sample flows until, as its temperature is lowered, the formation of ice crystals blocks the passage. The sample is admitted to the passage in the cylinder from a reservoir which is made of a vertical glass tube open at the upper end, its lower end connected to the cylinder by means of a rubber stopper and a length of brass tubing. Flow of the liquid from the reservoir into the 1.5-mm. passage is controlled by sliding a rod in and out of the hole in the rubber stopper.

The brass cylinder containing the test passage is cooled by inserting it into a brass tube which is soldered to a copper box filled with solid carbon dioxide ("dry ice"). Both the copper box and the attached tube are enclosed in a thermally insulated wooden box. The temperature of the cylinder is obtained from the dial of a bimetallic thermometer whose stem passes through the center of the cylinder. As the tem-

* Communicated by the Director.

perature rapidly falls below the freezing point of water, the valve in the reservoir is opened at about 10-deg. intervals until no more liquid flows from the exit tube in the brass cylinder. The cylinder is then removed from the cold tube and promptly placed in a hole provided in the wooden cover of the insulated box. As the cylinder slowly warms, the exit tube is watched, and when the second drop of liquid falls, the temperature is read. This temperature is the lowest at which the liquid being tested will circulate through the passages in an automobile radiator.

The determination requires from 3 to 6 min. depending upon the freezing point of the solution. Approximately two pounds of dry ice will suffice to keep the device operating for 8 to 10 hr.

Tests were made at NBS on antifreeze solutions obtained from a number of car owners selected at random. The maximum difference between readings made on six of the solutions by three different operators using the new antifreeze testing device was 2° F. for a given solution, and the average spread was 1° F. The minimum protection temperatures found were usually slightly below the temperatures at which the various solutions first show formation of ice crystals. Estimates given by service stations for the protection afforded by the solutions were found to vary as much as 30 deg. from the readings obtained with the NBS device. It is believed that an inexperienced operator using the NBS antifreeze tester should obtain protection temperatures that can be depended upon to ±2° F.

Automotive antifreezes have been a subject of investigation at NBS for many years. These studies, performed largely for other Government agencies, have included not only simulated and actual service tests of antifreezes but also basic investigations of the physical and chemical properties of antifreeze compounds and of the materials used in the cooling system of a car. As a result, NBS has been able to advise motorists on the proper use of antifreezes[1] and to warn them of the harmful and often dangerous effects of certain types of antifreezes.

PHOTOELECTRIC INTERFEROMETER FOR HIGH-POLYMER RESEARCH

A recording photoelectric interferometer recently developed by Dr. R. N. Work of the National Bureau of Standards greatly simplifies the determination of transition temperatures in natural and synthetic rubbers and other high polymers. The fully automatic instrument[2]

[1] Practical information on this subject, in a form designed to be useful to the average automobile owner, is given in NBS Circular 474, "Automotive Antifreezes," available from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., at a cost of 15 cents a copy.

[2] For further technical details, see "A Photoelectric Recording Interferometer for Measurement of Dimensional Changes," by Richard N. Work, *J. Research NBS*, Vol. 47, p. 80 (1951) RP 2230.

observes and plots the varying length of a polymeric sample against temperature over the range from −185° to +185° C. Transition temperatures are then readily obtained as discontinuities in the plotted curve or in its slope.

The new interferometer was developed in connection with a broad program now under way at NBS which has as its object the design of new polymers having specified characteristics. A knowledge of the temperatures at which transitions take place in these materials is needed in order to predict the temperature range over which a given polymer will have useful mechanical properties. An important current phase of the program which is being sponsored by the Office of Naval Research relates to the development of low-temperature rubbers for use in the arctic or in high-altitude flight. Rubbers become brittle or stiff as they undergo transitions at low temperatures, and NBS is seeking data that will aid in relating these changes to the molecular structure of the rubbers.

Several years ago the Bureau applied the interferometer to the location of transition points, using it to measure changes in the length of a polymeric specimen with varying temperature. In this type of application, three thin specimens are placed so as to separate two optically flat, transparent plates that are illuminated with parallel, monochromatic light perpendicular to the plane of their faces. If the plates are nearly parallel, the light reflected from the bottom surface of the top plate interferes with that reflected from the top surface of the bottom plate either constructively or destructively to form a pattern of interference fringes. Now, if the thicknesses of the specimens change with a variation in temperature, the separation of the plates will be altered, and there will be a corresponding variation in the fringe pattern as shown by a motion of the fringes. The fringes are observed in a suitable optical system, and the number passing a given point in the field of view is counted. Then the change in separation of the plates at the point of observation, and hence the change in length of the specimen near that point, is given by the following relation:

$$\Delta 1 = \frac{\Delta N \lambda}{2},$$

where $\Delta 1$ is the change in separation, ΔN is the number of fringes passing the point of reference, and λ is the wavelength of the light used.

Because the visual interferometric method requires the continuous and undivided attention of an operator, it has not been widely adopted. To avoid the tedious counting of fringes, various photographic methods have been tried. However, these methods all involve the processing of photographic film, and the data must still be plotted by hand. The NBS photoelectric interferometer eliminates all hand operations, presenting the plotted data on a record chart in a form suitable for

immediate determination of transition temperatures and for estimation of coefficients of expansion.

In the NBS device, a photomultiplier tube is used to detect the changes in light intensity at a reference point in the fringe pattern as the fringes move past this point. The amplified output of the tube is automatically plotted against time on a strip chart recorder, which is useful in monitoring the phototube output. A switch actuated by the recorder movement produces a current pulse upon the passage of each fringe. This current pulse actuates a mechanism which moves the chart of a second recorder a unit distance for each fringe. At the same time the pen of the second recorder is actuated by changes in the temperature of the specimen, as indicated by the emf. of a thermocouple embedded in a piece of material similar in size to the specimen and similarly located. Since changes in fringe count are proportional to changes in length, the record on the second recorder provides a plot of length of specimen versus temperature.

In the interferometer constructed at NBS, a helium tube is used as a source of light. After traversing an iris diaphragm, which limits the effective size of the source, the light is rendered parallel by a lens and is then deviated and dispersed in passing through a Pellin-Broca prism. By changing the orientation of the prism, light of a wavelength corresponding to one of the spectral lines in the source may be made to fall perpendicularly upon the interferometer plates, which are located at or near the focal plane of the lens. The reflected light returns along nearly the same path to form an image of the source at the iris diaphragm. The image of the interferometer with its interference fringes is observed through a converging lens system.

For a satisfactory fringe pattern, the interferometer plates must be parallel within a few wavelengths of light. Otherwise too many fringes will be observed, making counting difficult or impossible. To adjust the plates more easily for parallelism, quartz wedges are placed between the lower interferometer plate and the sample. The separation of the plates can then be varied slightly at each of the specimens by moving the corresponding wedge in or out. This adjustment can be made while the specimen holder is enclosed in a thermostat. Use of the wedges simplifies considerably the preparation of the specimens, permitting wider tolerances in their thicknesses.

The NBS photoelectric interferometer is particularly well adapted to survey work where transitions must be located rapidly in a large number of materials. The data can be processed with a minimum of effort, and a precision of $\pm 0.5°$ C. or better in the location of transition points can be realized. Values of coefficient of expansion thus obtained for rubberlike materials are reproducible to at least ± 5 per cent.

THE FRANKLIN INSTITUTE

MEDAL DAY PROCEEDINGS

The annual reception, dinner, and presentation of awards, known as "Medal Day," took place at The Franklin Institute on Wednesday, October 17, 1951. The reception began at 6:30 P.M. and dinner was served at 7:30 P.M. Mr. Richard T. Nalle, President of the Institute, presided at the dinner and presented the subsequent awards.

RECEPTION

The usual reception preceded the dinner and was attended by 349 persons. Immediately following the reception and just before dinner was served in Franklin Hall, Mr. Nalle requested the guests to face the flag above the Franklin statue while Mr. Guy Marriner, director of music at The Institute, played the National Anthem.

REMARKS OF THE PRESIDENT

MR. NALLE: "Tonight we have gathered to pay tribute to a group of individuals who have dedicated their talents and energies to the investigation of scientific problems. The results of this work have contributed both to our knowledge and, directly or indirectly, to raising our standard of living.

"Such a result is assuredly in keeping with the philosophy of Benjamin Franklin. That great American and world citizen had the deepest respect for all phases of science, but particularly for its application to the welfare of the people. He would certainly approve of the work of the scientists gathered here.

"It is appropriate to honor the memory of the man whose life and works strongly inspired and influenced the founders of the Institute.

"Therefore, I propose a toast, ladies and gentlemen, on this Medal Day to the living memory of Benjamin Franklin."

* * *

MR. NALLE (*continued*): "Honored guests, members of The Franklin Institute, and friends:

"On behalf of The Franklin Institute, it is with pleasure that I take this opportunity to welcome you to this traditional ceremony—the awarding of the Medals for 1951 by the Institute. However, before we proceed, I extend our particular appreciation to the Hostess Committee of The Franklin Institute for their assistance with the floral decorations for the evening."

STATED MONTHLY MEETING

MR. NALLE: "This day marks the regular stated October meeting of The Franklin Institute. The minutes of the last Stated Meeting in May have been published in the June issue of the JOURNAL OF THE FRANKLIN INSTITUTE and, if there are no corrections or additions, they are declared approved as printed.

"It is customary to elect recipients of the Franklin Medal to Honorary Membership in The Franklin Institute. This has been done in the case of Sir James Chadwick, to whom the certificate of Honorary Membership will be presented, *in absentia*, this evening with the Franklin Medal.

"With us tonight are former recipients of Medals of The Franklin Institute. As these names are read, and the award each person has received is mentioned chronologically in the order of the year of presentation, will each Medalist please rise and remain standing until the full roll is completed? I suggest that our applause be withheld until all are standing. I now call upon Dr. John Frazer, Secretary of the Committee on Science and the Arts, to read the roll of the former Medalists.

FORMER MEDALISTS ATTENDING MEDAL DAY—1951

Year	Medalist	City	Medal
1904	Dr. G. H. Clamer	Philadelphia, Pa.	Cresson
1905	Mr. Theodore G. Alteneder	Philadelphia, Pa.	Longstreth
1911	Dr. Joseph S. Hepburn	Philadelphia, Pa.	Longstreth
1921	Dr. Joseph S. Hepburn	Philadelphia, Pa.	Certificate of Merit
1915	General Charles D. Young	Philadelphia, Pa.	Longstreth
1948	General Charles D. Young	Philadelphia, Pa.	Henderson
1916	Dr. John V. N. Dorr	Westport, Conn.	Scott
1921	Dr. L. H. Adams	Washington, D. C.	Longstreth
1923	Mr. Harry S. Parks	Pottstown, Pa.	Longstreth
1924	Mr. Thomas C. McBride	Philadelphia, Pa.	Longstreth
1927	Mr. James F. Smathers	Poughkeepsie, N. Y.	Longstreth
1932	Mr. Thomas R. Harrison	Philadelphia, Pa.	Certificate of Merit
1937	Dr. Rupen Eksergian	Philadelphia, Pa.	Henderson
1945	Dr. Rupen Eksergian	Philadelphia, Pa.	Levy
1937	Mr. John S. Haug	Philadelphia, Pa.	Longstreth
1938	Mr. Stewart S. Kurtz, Jr.	Philadelphia, Pa.	Levy
1939	Dr. N. K. Chaney	Philadelphia, Pa.	Potts
1939	Mr. E. Burke Wilford	Philadelphia, Pa.	Certificate of Merit
1942	Mr. Walter Larkin	Norristown, Pa.	Certificate of Merit
1944	Mr. J. B. Ennis	Paterson, N. J.	Henderson
1947	Mr. E. G. Ackart	Wilmington, Del.	Newcomen
1947	Mr. Karl P. Billner	Philadelphia, Pa.	Brown
1948	Mr. Nicholas F. Arone	Philadelphia, Pa.	Longstreth
1949	Mr. J. Presper Eckert, Jr.	Philadelphia, Pa.	Potts
1950	Dr. Kenneth C. D. Hickman	Rochester, N. Y.	Wetherill
1950	Dr. Eugene Paul Wigner	Princeton, N. J.	Franklin

MR. NALLE: "Thank you, gentlemen.

"As is customary in the course of our Stated Meetings, I now call

on the Executive Vice President and Secretary of the Institute, Dr. Henry Butler Allen, for his report. Dr. Allen."

REPORT OF THE SECRETARY

"The Institute in 1951"

DR. ALLEN: "Mr. President, Ladies and Gentlemen: Last year I told you that The Franklin Institute was thankful to be able to help our country in these critical times. The past twelve months have brought intensification of this so called 'cold war.' We have been called upon to increase our preparedness efforts. We have responded.

"To this end our Laboratories for Research and Development have continued their expansion of facilities. But despite continuing work for our Armed Forces we offer research services to the industries of this area. During the past year new facilities have been set up for work in the fields of hydraulics and the basic properties of metals.

"The Bartol Research Foundation has been concerned in a multitude of activities. Prominent among these are the continued development of the high voltage accelerator and the construction of an exceptionally efficient ion source for use with it. The laboratory has also engaged upon three cosmic-ray expeditions—one in Minnesota, one in four B-29 flights between Canada and the equator, and a third in the mountains of West Virginia. The nuclear physics program and the program of thermionics have progressed very satisfactorily. A linear accelerator for electrons has been developed and is now engaged upon special research in the electronic field. In simple language, this all means the study of the atom—matter and energy. It is the present day continuation of Franklin's work in electricity.

"The Biochemical Research Foundation has conducted as its major effort the study of nucleic acid and cell division in relation to cancer. In addition, the Foundation has followed other lines, including the study of ultraviolet light, enzyme study of various character (particularly in regard to intra-cellular reactions), and the effects of radiation on biological material.

"The Museum and Planetarium have not stood still. An outstanding activity of the Museum during the past twelve months was the exhibition of the Ford Motor Company's Industrial Arts Awards entries, and Philadelphia was chosen as one of the three centers to hold exhibitions. The purpose of the awards is to promote the cultivation of craftsmanship among young people, and the exhibition held in this hall proved that industrial arts are being intelligently taught and vigorously practiced in the Eastern States.

"This encouragement of young people to develop ideas and manual skill is parallel with our efforts which have found expression in the annual Science Fairs conducted with the cooperation of the *Philadelphia*

Inquirer. The Science Fair this year furnished convincing evidence that there is an abundance of scientific talent in our local schools awaiting encouragement and development.

"An interesting feature of the museum attendance has been the unusually large number of foreign visitors. Several groups of students and delegates to international conventions have included a visit to the museum in their itineraries—proving, if further proof is need, that our Museum has attained recognition upon a wide scale.

"In the field of Museum Education, many special activities have been arranged including lectures, special assistance for Book Fair exhibition, Science Adventures for Young People, and tours for groups of international organizations.

"In the past 125 years, the Library has grown from a small collection of books and periodicals to one of 'the' libraries of science and technology. During the year, many gifts were received from friends, and several treasures were added to our rare book collection. We were presented with the complete library of the National Association of Watch and Clock Collectors.

"Our JOURNAL OF THE FRANKLIN INSTITUTE, on the occasion of its 125th anniversary last January, issued a symposioum 'Science and Tomorrow,' in which fourteen eminent scientists and engineers discussed possible future developments in science and technology. The Institute is proud of this contribution to scientific literature.

"The individuals and companies constituting the 'Friends of Franklin' numbered 345 in 1950 and contributed over 27,000 dollars toward the operating expenses of The Franklin Institute.

"Last Fall and this Spring eighteen joint and stated meetings of the Institute were held. The average attendance was 237.

"The membership of the Institute has reached a new high with over six thousand at the moment. These come from all over the country and from many foreign lands.

"In spite of all we are really accomplishing in the way of helping ourselves we, like other private institutions today, suffer from the disease Franklin called 'Lack O'Money.' Our Friends of Franklin group is a real help. The State contributes toward making up deficits. But, as our Board of Managers said in its current Annual Report:

> As has been pointed out in recent reports, the Institute needs funds for the development and enlargement of its Museum educational activities; for engaging in self-sponsored research work in its Laboratories; for the addition of books for its Library—and particularly for the binding and cataloguing of Library material to make it of real use to the public; and of course for carrying on its general routine, undramatic operations. The Institute appeals to those who believe in its work to help toward its support.

"The success of our many activities is greatly dependent upon our being able to reach the general public, to inform the people of what we are doing and to draw on them for their support. It is with the deepest

and most sincere gratitude that I acknowledge at this time the splendid support and encouragement we continue to receive from the local and out-of-town press, radio and television and other forms of communication. We hope we shall continue to earn their cooperation.

"Finally, I must mention one other activity of ours which is being continued, but on much too small a scale. It is the dissemination of specific advice from our Patron Saint, Benjamin Franklin on how to make ourselves better citizens. One of Franklin's dreams, for the answer of which he constantly worked, is expressed in a letter to his friend, Joseph Priestly, a scientist and minister. I quote:

> The rapid progress true science now makes, occasions my regretting sometimes that I was born so soon. It is impossible to imagine the height to which may be carried, in a thousand years, the power of man over matter. . . . O that moral science were in a fair way of improvement, that men would cease to be wolves to one another, and that human beings would at length learn what they now improperly call humanity.

"My good fellow staff members join with me in looking foward to showing you all we are doing whenever you have the opportunity of visiting us. And to you, our new medalists, may I remind you that you are now among our alumnae, and that Franklin Institute is your home whenever in Philadelphia."

MR. NALLE: "Thank you, Dr. Allen. For 127 years now, reports such as yours have been made on affairs of The Franklin Institute.

"During this more than a century and a quarter, the Institute has rendered public service through its science museum, scientific library and lectures and by acting in its earlier days as a custodian of the models of some of the many great scientific achievements that have been added to the world's knowledge. At the same time, it has attempted to convey to the public the significance of these advances.

"In addition, the individuals who have been responsible for these great discoveries and inventions have continually received encouragement in their special fields. And thus it is that we have been giving these awards, based upon the recommendations of our Committee on Science and the Arts, since 1835. As a matter of fact, the Institute has been awarding medals since 1825, and was among the first to use this form of recognition which has become of general practice today.

"Activities of this year's recipients range from aviation to atoms. Our industrial civilization is based upon scientific research and, whether or not we are thinking in terms of television, washing machines or nuclear physics, the scientists whose untiring efforts produce these things for us are the pioneers of our age. As such, they deserve our support and encouragement.

"These awards have been made possible by the far-sighted thinking of those who wished to make a concrete contribution for the promotion of worthy scientific endeavor.

"The Science and Arts Committee devotes the entire year to determining which outstanding scientific developments merit special recognition. The care and integrity exercised by this Committee for more than one hundred years have made these awards internationally known and highly regarded in scientific fields.

"Each Medalist is sponsored by the chairman of the sub-committee of the Science and Arts Committee which recommended him for the award. This Sponsor will read the citation accompanying the medal.

"Tonight at this stated meeting of The Franklin Institute, it is a matter of great regret that three of our Medalists are unable to be here. Sir James Chadwick is confined to his home because of illness. Messrs. Basil Albert Adams and Eric Leighton Holmes are absent because pressing duties connected with their work make it absolutely impossible for them to leave their country. Their medals will be sent to them after presentation here tonight to their countryman, Mr. A. K. Longair, who has been selected to stand as proxy.

"Now we will call on the various Sponsors to present their candidates. Will the Sponsors please take their places?"

PRESENTATION OF THE CERTIFICATES OF MERIT

(Founded in 1882)

(To John F. McKee, Research Engineer, Yarnall-Waring Company, Philadelphia, Pennsylvania; and Jean Mercier, President, Olaer Patent Company, Paris, France.)

MR. NALLE: "First, the Chair recognizes Mr. C. D. Galloway."

MR. GALLOWAY: "Mr. President, I present John F. McKee for an award.

"Mr. McKee has designed an efficient and compact steam trap, embodying a condensate relief valve that is controlled by the phenomena of varying pressures which occur in a chamber between two orifices arranged in series.

"This chamber pressure varies with the nature and properties, particularly the temperature and phase of the fluid flowing. Through the ingenious use of this phenomenon, he has designed a steam trap approximating the size of a globe valve for the corresponding diameter steam line, which is capable of handling high temperatures and pressures.

"I present John F. McKee, of Philadelphia, Pennsylvania, as a candidate for a Certificate of Merit, 'In consideration of the development of the design of a compact, simple, rugged steam trap utilizing the principle of the varying pressure in the intermediate chamber between two orifices.' "

MR. NALLE: "Mr. McKee, by virtue of the power vested in me as President of The Franklin Institute of the State of Pennsylvania, I

present to you this Certificate of Merit and the Report which accompanies it."

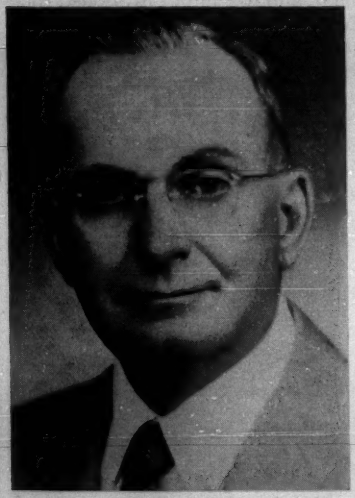
MR. MCKEE: "Thank you."

MR. NALLE: "The Chair recognizes Dr. James Barnes."

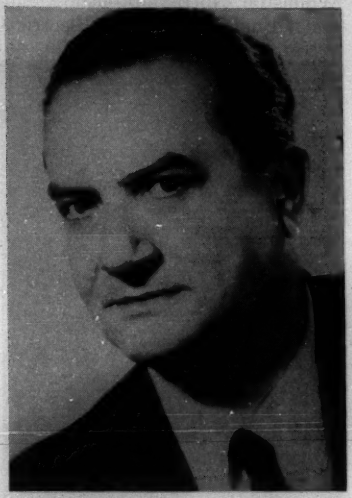
DR. BARNES: "Mr. President, I present Jean Mercier for an award.

"An hydraulic accumulator is a mechanism in which the potential energy of a fluid under pressure can be stored to do useful work when called upon by the circuit in which it is used.

"Mr. Mercier developed an accumulator consisting of a steel bottle of special alloy steel, inside of which is installed a synthetic rubber bag. Oil under pressure is admitted by means of a pump to the bottle and air under pressure to the bag, so that, when energy is



John F. McKee



Jean Mercier

used in the oil system, the air in the bag expands to maintain the oil pressure within specified limits for intermittent duty.

"The principal uses for these accumulators are the following: compensator with pressure regulator or unloader valves; leakage compensators for holding rams; power brake circuits such as used on aircraft, rail cars, trucks and busses; emergency source for fluid power in airplanes, tank guns, etc., when pumps are destroyed; to supply lubricant to a group of bearings; and an auxiliary source of energy in intermittent duty systems.

"These accumulators are in wide use today.

"I present Jean Mercier, of Paris, France, as a candidate for a

Certificate of Merit, 'In consideration of new and important combinations of principles already known and for many inventions covering the details of the oleopneumatic accumulators.' "

MR. NALLE: "Mr. Mercier, by the same authority, I present to you this Certificate of Merit and the Report which accompanies it."

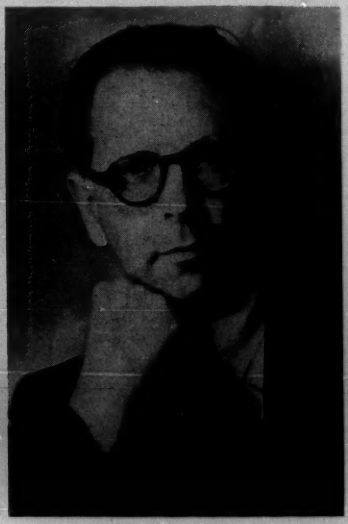
MR. MERCIER: "Thank you."

PRESENTATION OF THE HOWARD N. POTTS MEDALS

(Founded in 1906)

(To Basil Albert Adams, Research Chemist, Barry, Glamorgan, Wales, and Eric Leighton Holmes, Consulting and Research Chemist, Wollaston, Northamptonshire, England; and to Clifford M. Foust, Electrical Engineer, General Electric Company, Schenectady, New York.)

Basil Albert Adams



Eric Leighton Holmes

MR. NALLE "The Chair recognizes Dr. Julian W. Hill."

DR. HILL: "Mr. President, I present, *in absentia*, Basil Albert Adams and Eric Leighton Holmes for awards.

"The scientific contributions of Adams and Holmes lie in the field of chemistry known as ion exchange. An old and familiar example of ion exchange is the softening of hard water by passing it over certain minerals, which replace calcium ion in the water by sodium ion. In 1934, working in the government chemical research laboratory at Teddington, England, Adams and Holmes demonstrated that synthetic

resins, when suitably formulated, have ion exchange properties. Their discovery enormously increased the scope and usefulness of the ion exchange type of reaction. It has made possible the exchange of practically any ion, positive or negative, in contrast to the limited number of positive ions that earlier materials would exchange. One result is the preparation of perfectly pure water—not merely softened water—by ion exchange.

"This procedure is today operated industrially on a large scale. It was used during the war by flyers forced down at sea to desalt sea water. Synthetic ion exchange resins are also used for a host of other important purposes in industry, in the laboratory, and in medicine.

"I present, *in absentia*, Basil Albert Adams, of Glamorgan, Wales, and Eric Leighton Holmes, of Northamptonshire, England, to each of whom has been awarded a Howard N. Potts Medal, 'In consideration of their pioneering concept of the use of suitably designed synthetic organic resins for ion exchange, the discovery of anion exchange, the application of these principles to the preparation without distillation of pure water, and paving the way for the tremendous subsequent development in ion exchange materials and processes in science and industry.'"

MR. NALLE: "By the same authority, Mr. Longair, I present to Mr. Adams and Mr. Holmes, through you, these Howard N. Potts Medals and the Certificates and Reports which accompany them."

MR. LONGAIR: "Thank you."

MR. NALLE: "The Chair now recognizes Dr. Comfort A. Adams."

DR. ADAMS: "Mr. President, I present Clifford McClain Foust for an award.

"From the early beginnings of the aerial transmission of electrical energy, lightning storms have been the greatest source of service failures. Successful methods of protection were difficult to achieve, because neither qualitative nor quantitative information was available.

"In the year 1921, Dr. Steinmetz decided that to obtain concrete data it was necessary to build a device subject to laboratory control which would artificially reproduce effects similar to natural lightning, and constructed a Lightning Generator for 120,000 volts and 100,000 horsepower.

"Since then, additional Lightning Generators have been constructed, until there is now available an impulse generator capable of producing 10,000,000 volts of man-made lightning.

"Clifford M. Foust, native of Erie, Pennsylvania, and graduate of Carnegie Institute of Technology, in 1922 was assigned as engineering assistant to Dr. Steinmetz on lightning and insulating studies, and has been very active in high voltage work since then.

"Although the development of the Lightning Generator advanced the knowledge of lightning phenomena greatly, there were no definite

means of quantitatively measuring the discharges of man-made or natural lightning to correlate laboratory with field observations.

"The developments made by Mr. Foust in the field of measuring high voltage surges have made it possible to measure the effects of uncontrolled natural lightning and relate it to the controlled performance obtained in the laboratory.

"I present Clifford McClain Foust, of Schenectady, New York, as a candidate for a Howard N. Potts Medal, 'In recognition of his many contributions to the knowledge of high-voltage surge phenomena and the quantitative measurements furthering this knowledge through his development of accurate measuring devices.' "

Clifford M. Foust

MR. NALLE: "Mr. Foust, by the same authority, I present to you this Howard N. Potts Medal and the Certificate and Report which accompany it."

MR. FOUST: "Thank you."

PRESENTATION OF THE LOUIS E. LEVY MEDAL

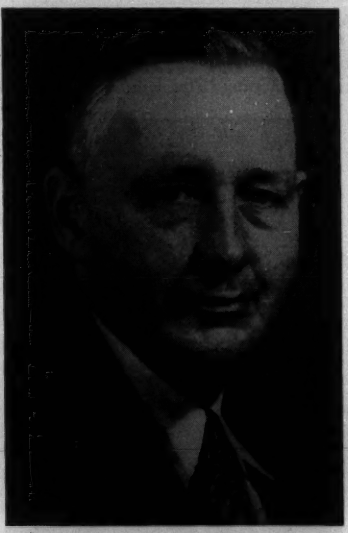
(Founded in 1923)

(To Albert Charles Walker, Research Engineer, Bell Telephone Laboratories, New York, New York.)

MR. NALLE: "The Chair recognizes Dr. Winthrop R. Wright."

DR. WRIGHT: "Mr. President, I present Albert Charles Walker for an award.

"Modern communication systems are dependent upon the production and detection of alternating electrical currents whose frequencies are maintained constant within narrow limits. The quartz crystal, when properly cut and mounted, is widely used by these industries as both monitor and filter for frequencies in the approximate range from 50 kilocycles per second to 50 megacycles per second. These crystals have been cut from natural quartz, the most abundant deposits of which occur in Brazil, but the demand has begun to exhaust the known supply.



Albert Charles Walker

"Our Medalist has been instrumental in growing artificial crystals to replace those of natural quartz. His first success was in preparing single crystals of ethylenediamine tartrate, a material which now replaces quartz in many applications made by the telephone industry.

"He then approached the problem of growing single crystals of clear quartz, a matter which has interested geologists for at least one hundred years. His work was naturally based on that of many earlier workers. Where they required many months to grow even minute crystals, he has succeeded in growing single crystals weighing as much

as a pound in a matter of a few weeks. These crystals are not yet grown commercially but his work has laid the foundation for such growth when the need arises.

"I present Albert Charles Walker, of Short Hills, New Jersey, 'In recognition of his outstanding paper, "Growing Piezoelectric Crystals," appearing in the December, 1950, issue of the JOURNAL OF THE FRANKLIN INSTITUTE.' "

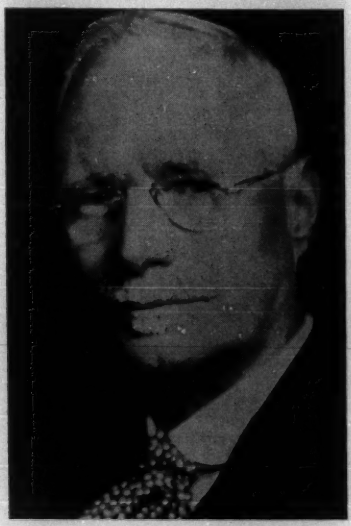
MR. NALLE: "Dr. Walker, by the same authority, I present to you this Louis E. Levy Medal and the Certificate and Report which accompany it."

DR. WALKER: "Thank you."

PRESENTATION OF THE GEORGE R. HENDERSON MEDAL

(Founded in 1924)

(To Hermann Lemp, Consulting Engineer, Ridgewood, New Jersey.



Hermann Lemp

MR. NALLE: "The Chair now recognizes Mr. J. B. Ennis."

MR. ENNIS: "Mr. President, I present Hermann Lemp for an award."

"The Diesel Electric Locomotive has rapidly replaced steam locomotives due to outstanding performance and availability A major contribution to this performance is the Electric Drive which makes possible large starting tractive force and provides power at the higher

speeds, consistent with the power capacity of the engine. A major problem before Lemp's contribution, was to load the engine to full capacity throughout the speed range without stalling the engine at overloads. The Lemp system was the first successful electric transmission for the internal combustion motive power unit to provide automatic engine loading through generator field control.

"Along with this contribution, it required a fundamental grasp of electric machinery and circuit design. The control, along with generator design, must meet varying current and voltage requirements in order to transmit power from an engine running at nearly constant speed with limited torque to the large variation in speed at the drivers and correspondingly large torque amplification in starting.

"I present Hermann Lemp, of Ridgewood, New Jersey, as a candidate for the George R. Henderson Medal, 'In view of his basic contributions to the Electric Transmission through field control, thereby improving the performance characteristics and engine loading of Diesel Electric locomotives.' "

MR. NALLE: "By the same authority, Mr. Lemp, I present to you the George R. Henderson Medal and the Certificate and Report which accompany it."

MR. LEMP: "Thank you."

PRESENTATION OF A JOHN PRICE WETHERILL MEDAL

(Founded in 1925)

(To Samuel C. Collins, Professor of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts.)

and

PRESENTATION OF THE EDWARD LONGSTRETH MEDAL

(Founded in 1890)

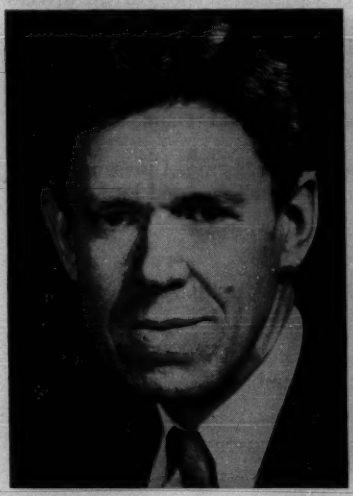
(To Howard O. McMahon, Physicist, Arthur D. Little, Incorporated, Cambridge, Massachusetts.)

MR. NALLE: "The Chair recognizes Dr. Thomas D. Cope."

DR. COPE: "Mr. President, I present Samuel C. Collins and Howard O. McMahon for awards.

"The extraordinary phenomena and properties of matter at temperatures near the absolute zero have become of vital interest both to the scientist and the technologist. These low temperatures can be reached only by the use of liquid helium. A decade ago, helium could be liquefied at only a score of places in the entire world. Today, it can be liquefied in any establishment, in a small room, and at moderate cost, with highly dependable equipment. This great and sudden increase in the availability of liquid helium has resulted from inventions and developments made by the gentlemen just introduced.

"I present Samuel C. Collins, of Cambridge, Massachusetts, the inventor, as a candidate for a John Price Wetherill Medal, and Howard O. McMahon, also of Cambridge, Massachusetts, pupil of Professor Collins and coworker in subsequent development, as a candidate for an Edward Longstreth Medal, 'In consideration of the invention and subsequent development of the first liquefier of helium to operate without the aid of external refrigerants, an admirably designed, reliable machine which is produced in quantity and has materially increased the number of laboratories and persons engaged in work at ultra low temperatures.' "



Samuel C. Collins

Howard O. McMahon

MR. NALLE: "By the same authority, I present to you, Professor Collins, as the inventor, the John Price Wetherill Medal and the Certificate and Report which accompany it; and to you, Dr. McMahon, as coworker in subsequent development, the Edward Longstreth Medal and the Certificate and Report which accompany it."

PROFESSOR COLLINS: "Thank you."

DR. MCMAHON: "Thank you."

PRESENTATION OF JOHN PRICE WETHERILL MEDALS

(To Reid Berry Gray, Consulting Engineer, Baltimore, Maryland; and Gaylord W. Penney, George Westinghouse Professor of Engineering, Carnegie Institute of Technology, Pittsburgh, Pennsylvania.)

MR. NALLE: "The Chair recognizes Dr. William G. Schmidt."

DR. SCHMIDT: "Mr. President, I present Reid Berry Gray for an award.

"Mr. Gray pioneered the development of storage of fuel in aircraft wings in flexible walled containers placed in the cavities in the wings formed by wing structure itself. The value of this development was that it did away with leaky fuel tanks, in both military and commercial planes, which were dangerous from point of view of fire hazard and uneconomical from point of view of lost fuel. Furthermore, Mr. Gray's flexible walled containers made it possible to utilize space which otherwise would be wasted.

Reid Berry Gray

"This cell was made to resist chemical action of fuels over long periods. It was flexible and lightweight. It was leak-proof and puncture-proof because of its self-sealing qualities. Since it was flexible, it was not required to be structurally rigid because the loads were borne by the walls of the cavity into which it was inserted.

"This 'Mareng' cell—a contraction of Martin Engineering—utilized the property of the swelling of specially treated crude rubber upon contact with gasoline. When the cell was punctured by bullets, the aperature would be instantly sealed. The Glenn L. Martin Company were the first to use these cells in military aircraft in 1937. Over

two million Mareng cells were manufactured and used in aircraft during World War II.

"Because these cells utilized waste space in the plane and did not waste fuel by leakage, they greatly increased the range of aircraft flight. Cells became important for commercial air transport by preventing disastrous fires resulting from bad landings.

"The cell was used in PT boats and jeeps.

"It was used in underground storage depots or cavities in the earth, serving as advance storage depots during the rapid advance of our armed forces in World War II.

Gaylord Wallis Penney

"The Pennsylvania Railroad put the flexible cells into box cars for the transport of oil and gasoline.

"As a measure of safety and economy, this cell has contributed much, militarily and commercially.

"I present Reid Berry Gray, of Baltimore, Maryland, as a candidate for a John Price Wetherill Medal, 'For his development of collapsible and self-sealing fuel cells affording to aircraft greater safety, ability to carry more fuel and, consequently, increased non-stop range of flight, and a proven record to save the lives of aircraft crews.' "

MR. NALLE: "By the same authority, Mr. Gray, I present to you a

John Price Wetherill Medal and the Certificate and Report which accompany it."

MR. GRAY: "Thank you."

MR. NALLE: "The Chair recognizes Mr. Ralph H. McClarren."

MR. MCCLARREN: "Mr. President, I present Gaylord W. Penney for an award.

"Professor Penney has made a notable achievement in the field of mechanic arts which has contributed materially to the health and welfare of mankind.

"While associated with the Westinghouse Electric and Manufacturing Company, he perfected an electrostatic device to separate dust and other solid material particles from air. His work is distinguished from previous commercial process units by utilizing lower voltages, preventing the generation of too much unwanted ozone, the saving of space and materials and, consequently, making possible the use of his device for cleaning the air we breathe. When used in connection with air conditioning and ventilating equipment, the cleaner and practically dust-free air aids health and saves cleaning costs. Known commercially as the Precipitron and Trion, the device has been in use and on the market for several years.

"I present Gaylord W. Penney, of Pittsburgh, Pennsylvania, as a candidate for a John Price Wetherill Medal, 'In consideration of his work in the development of a practical and commercially used electronic precipitator to remove particles of matter from ventilating air.' "

MR. NALLE: "Professor Penney, by the same authority, I present to you this John Price Wetherill Medal and the Certificate and Report which accompany it."

PROFESSOR PENNEY: "Thank you."

PRESENTATION OF THE FRANK P. BROWN MEDAL

(Founded in 1938)

(To Samuel Arnold Greeley, Sanitary Engineer, Chicago, Illinois.)

MR. NALLE: "The Chair recognizes Mr. Coleman Sellers, III."

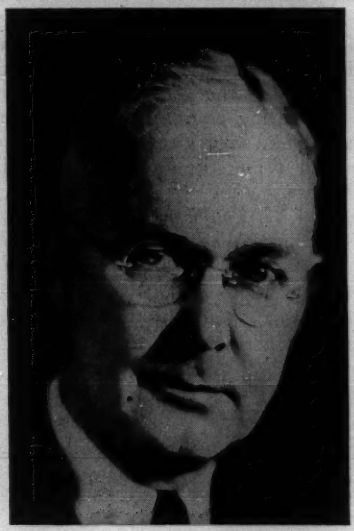
MR. SELLERS: "Mr. President, I present Samuel Arnold Greeley for an award.

"Great progress has been made in the past twenty-five years in the science of Sanitary Engineering. Our candidate has had a large part in this progress, not only because of his outstanding engineering achievements, but because he has disseminated information to others, greatly assisting them in the design and construction of sanitary works.

"Our Medalist has had a long and brilliant record of accomplishments. He has been engaged as consultant by many municipalities

including New York, Chicago, Philadelphia, Los Angeles, Boston, Washington, Kansas City, Toronto, Buffalo, Minneapolis, St. Paul, and many smaller cities. In addition, his work has taken him to South America, England and the Continent. During both World Wars, he was retained by various branches of the Federal Government in a consulting capacity.

"Mr. Greeley has presented a number of valuable papers before engineering societies and has written many articles for technical periodicals. He has also served on many important committees having to do with the various aspects of sewage treatment and Municipal Cleansing Practice.



Samuel Arnold Greeley

"I present Samuel Arnold Greeley, of Winnetka, Illinois, as a candidate for the Frank P. Brown Medal, 'For his leadership in the profession of Sanitary Engineering and his many contributions to knowledge in that field which have particularly improved the welfare of urban populations.' "

MR. NALLE: "Mr. Greeley, by the same authority, I present to you this Frank P. Brown Medal and the Certificate and Report which accompany it."

MR. GREELEY: "Thank you."

PRESENTATION OF THE FRANCIS J. CLAMER MEDAL

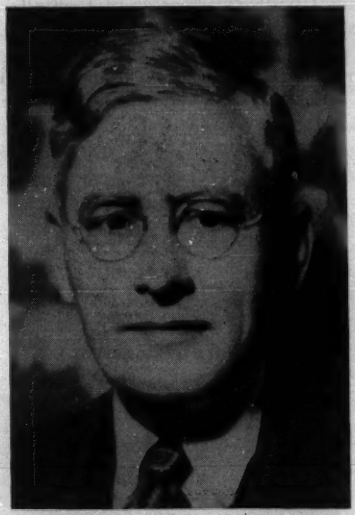
(Founded in 1943)

(To John Chipman, Professor of Metallurgy, Massachusetts Institute of Technology, Cambridge, Massachusetts.)

MR. NALLE: "The Chair recognizes Dr. G. H. Clamer."

DR. CLAMER: "Mr. President, I present John Chipman for an award.

"The suitability of steel for its many purposes depends on a proper control of the chemical reactions which take place between the gaseous fuel, the slag and the molten metal during its melting and refining.



John Chipman

Steelmaking is carried on at a temperature in the neighborhood of 3000 deg. F. and the task of carrying on researches under controlled conditions at such high temperatures has been such a difficult one that it has been only during the past twenty-five years that the problems involved have been solved sufficiently to enable the prediction of the type and extent of chemical reactions which will take place in a bath of steel under a given set of conditions. To Dr. Chipman, more than to any other single individual during the past twenty years, belongs the credit for advancing steel melting technology to its present quantitative and sound theoretical basis.

"I present John Chipman, of Cambridge, Massachusetts, 'In

recognition of his contributions as an individual and as a teacher to the application of the theories of physical chemistry to steelmaking practice.' "

MR. NALLE: "Professor Chipman, by the same authority, I present to you this Francis J. Clamer Medal and the Certificate and Report which accompany it."

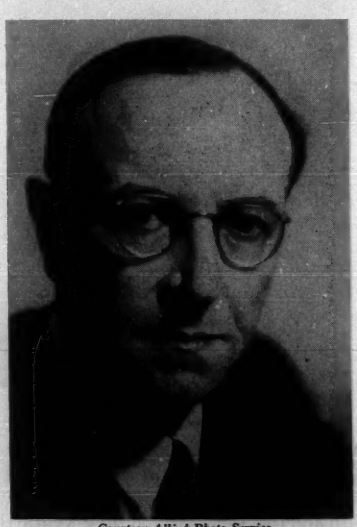
PROFESSOR CHIPMAN: "Thank you."

PRESENTATION OF THE FRANKLIN MEDAL

(Founded in 1914)

(To Sir James Chadwick, Master of Gonville and Caius College, Cambridge University, England.)

MR. NALLE: "The Chair now recognizes the final Sponsor of the evening, Mr. C. H. Masland, II, to present the candidate for the Franklin Medal."



Courtesy Allied Photo Service

Sir James Chadwick

MR. MASLAND: "Mr. President, I present, *in absentia*, Sir James Chadwick for an award.

"The English language contains many apt similes. Among them is the statement that a certain task is more difficult than finding a needle in a haystack. Certainly the task which Sir James Chadwick set himself and accomplished, falls in that class.

"A number of years before the discovery of the neutron by Sir James, Lord Rutherford had predicted that such a particle should be found as a part of the atom. Sir James and others spent considerable time in looking for the neutron 'needle' in the atomic 'haystack.' Unfortunately, you cannot see a neutron, nor will a neutron stick your finger, nor can you smell it or taste it or hear it. It is altogether too small for any of these things. Consequently, Sir James had to find the neutron by observing its action on other things which are visible. In order to identify this particle which he called a neutron, it was necessary to measure its approximate mass and its charge and to measure its velocity as it penetrated various materials. Then he needed to show that, in these characteristics, this type of particle differs from others. These things Sir James Chadwick has done in proving that the neutron is one of the particles existing in the atomic nucleus and that it has a mass approximately equal to that of a proton and that it has no net charge.

"I present, *in absentia*, Sir James Chadwick, of Cambridge, England, as a candidate for the Franklin Medal, 'In consideration of his outstanding work in nuclear physics, especially his identification of the neutron as a part of the nucleus of the atom.' "

MR. NALLE: "By the authority vested in me as President of The Franklin Institute, I present, *in absentia*, to Sir James Chadwick, through Mr. A. K. Longair, this Franklin Medal with its accompanying Certificate and Report, and a Certificate of Honorary Membership in The Franklin Institute."

MR. LONGAIR: "Thank you."

MR. NALLE: "I will ask Dr. Allen, as Secretary of the Institute, to assist Mr. Longair in making arrangements to send these awards to their recipients in England.

"The Sponsors may now resume their places.

"It is now my pleasure to present to you Mr. A. K. Longair, His Majesty's Assistant Scientific Attaché, and a physicist in his own right, who will read for us the paper entitled 'The Beginnings of the Atomic Bomb,' which Sir James Chadwick, the 1951 Franklin Medalist, has prepared for this evening. Mr. Longair."*

After Mr. Longair had read this paper, Mr. Nalle conveyed to him the thanks of the Institute, dismissed the assembly with a cordial word and declared the meeting adjourned.

* See page 453 for the text of this paper.

MINUTES OF THE STATED MEETING

November 21, 1951

The November stated meeting of the The Franklin Institute was held in the Lecture Hall on Wednesday evening, November 21, 1951, with approximately 260 persons attending.

The President called the meeting to order at 8:30 P.M. He announced that the minutes of the stated meeting for October had been printed in the November issue of the JOURNAL of The Institute and if there were no corrections or changes therein, they would stand approved as printed. There were none and they were approved.

In the absence of the Secretary, H. V. Bail, assistant secretary, acted as secretary of the meeting. He reported that the following elections to membership had been recorded since April 30, 1951:

Honorary	1
Active Life	1
Active	210
Associate	198
Student	71
Total	481

The total Institute membership as of November 20, was 6,086.

The Secretary also announced that the Planetarium was this year presenting a new Christmas show entitled, "The First Christmas," which would run through the month of December.

The President then introduced the guest speaker, Dr. Hubert N. Alyea, whose subject was "Atomic Energy: Weapon for Peace." Dr. Alyea, an Associate Professor of Chemistry at Princeton University, carried out many interesting experiments which illustrated differences between chemical explosives, A-bombs and H-bombs, including a description of the effects of an atomic explosion upon civilians a mile or two away. He related how atomic reactors, built originally for military purposes, are broadening scientists' peace-time horizons, and concluded with some personal thoughts on the importance of political efforts to establish a lasting peace by means of, rather than in spite of, atomic weapons.

After a question and answer period, Dr. Alyea was given a rising vote of thanks as the meeting adjourned.

H. V. BAIL
Secretary of the Meeting

JOURNAL OF THE FRANKLIN INSTITUTE

The following papers will appear in the JOURNAL within the next few months:

GOLOMB, MICHAEL AND EUGENE USDIN: A Theory of Multidimensional Servomechanisms.

AYRE, ROBERT S.: Transient Vibration of Linear Multi-Degree-of-Freedom Systems by the Phase-Plane Method.

MCCLESKY, CHARLES S., JR.: Resistance of Plates with Small Electrodes.

ARCHIBALD, FRANK R.: The Step Shaped Film Applied to a Journal Bearing.

TUSKA, C. D.: Pictorial Radio.

NORINDER, HARALD: Investigation of Resistance and Power in Experimental Lightning Discharges.

MOON, PARRY: A Proposed Musical Notation. (With several discussions by outstanding musicians.)

MANDEVILLE, C. E. AND E. SHAPIRO: Radiations from Radioactive Rhodium (105).

SMITH, J. J. AND P. L. ALGER: The Use of the Null-Unit Function in Generalized Integration.

LIBRARY

The Committee on Library desires to add to the collections any technical works that members may wish to contribute. Contributions will be gratefully acknowledged and placed in the library. Duplicates received will be transferred to other libraries as gifts of the donor.

Photostat Service. Photostat prints of any material in the collections can be supplied on request.

The Library and reading room are open on Mondays, Tuesdays, Fridays and Saturdays from 9 A.M. until 5 P.M.; Wednesdays and Thursdays from 2 P.M. until 10 P.M.

RECENT ADDITIONS

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COMMITTEE ON SCIENCE AND THE ARTS

(Abstract of Proceedings of Stated Meeting held Wednesday, November 14, 1951.)

HALL OF THE COMMITTEE,
PHILADELPHIA, NOVEMBER 14, 1951.

DR. RUPEN EKSERGIAN in the Chair.

The following report was presented for final action:

No. 3233: Speedomax Recorder.

This report recommended the award of a John Price Wetherill Medal to Albert J. Williams, Jr., of Philadelphia, Pennsylvania, "In recognition of his invention of the Speedomax, incorporating for the first time an electronic balance detector."

JOHN FRAZER,
Secretary to Committee.

MEMBERSHIP

ACTIVE MEMBERS ELECTED AT THE MEETING OF THE BOARD OF MANAGERS, NOVEMBER 21, 1951

ACTIVE FAMILY

Leonard E. Liss
William H. Metzgar
Frederick H. Stafford
Marmaduke Tilden

ACTIVE

Charles L. Bolton
Harold G. Connell
Albert Dickman, Ph.D.
Van Horn Ely, Jr.
Alex E. Farkas
E. A. Filmyer
Walter J. Gailus
B. T. Gordon
Earl F. Gorman
Robert F. Hart
Albert C. Hellwig
Walter F. Hoover
Clayton Hough
Laurence Keltz
Arthur H. Kuljian
Russell S. Lyman
Anthony J. Macaluso
John W. May
Ellsworth Joseph McCloskey
Samuel T. Melvin, Jr.
John E. Orban
Walter H. Pearson, III
Meade W. Pennybacker
Philip Persemperi
Donald G. Peterson
William A. Raub
Edwin M. Rittenhouse
John E. Rodenhausen
F. Charles Ruling
H. Lee Scott, D.D.S.
Albert W. Spitz
Harry G. Stewart
Ferdinand E. Trudel, Jr.
George A. Vare
William K. Waldron
William K. Walker
Monroe E. Wenger
Col. Howard G. Whitpan

ACTIVE NON-RESIDENT

Oleg Yadoff, Ph.D., Sc.D.

NECROLOGY

Christian L. Bauer '43
Philip J. Baur '41
Conrad R. Bready '43
Franke H. Cooke '42
William B. Eagleson '36
Edwin H. Hammer '13
Michael J. Melody '50
W. H. Pearson '49
William E. Ridenour '36
Gordon R. Winter '51
J. Lester Woodbridge '21

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION

DR. ELLICE McDONALD, DIRECTOR

Abstract of **Sonic Radiation Effects on Rats.**—E. D. DAY, D. C. FLETCHER, G. M. NAIMARK AND W. A. MOSHER (*J. Aviation Med.*, 22, 316(1951)). Sonic radiation of the type emitted most intensely by turbo-jet engines was found to be a stress-producing agent in rats. The desoxypentosenucleic acid content per nucleus of the liver and adrenals was not found to change. No indication was found of secondary effects of stress due to sonic radiation. Rats kept in isolation were found to be less resistant, than rats conditioned by sound and confusion common to most animal rooms, to the lethal effects of sonic radiation.

Abstract of **Alkaline Phosphatases in Fixed Plant Cells.**—M. H. ROSS AND J. O. ELY (*Experimental Cell Research*, 2, 339 (1951)). Alkaline phosphatase activity in fixed plant cells has been demonstrated cytochemically. Presumably cytochemical findings on plant alkaline phosphatases had been lacking because glycerophosphate, which is not hydrolyzed by fixed plant cells, had been used as the substrate. Alkaline phosphatase activity in the onion and corn nuclei has been compared with the activity in rat tissues. In the plant tissues, hydrolysis of phosphates was demonstrated when the substrates guanylic acid, adenosine diphosphate, adenosine triphosphoric acid, diphosphopyridine nucleotide, hexosediphosphates and inorganic pyrophosphate and metaphosphate were used. When the substrates glycerophosphate, adenylic acid and hexosemonophosphates were used, hydrolysis was not found. In the animal tissues however, hydrolysis was demonstrated of all organic phosphoesters employed and of sodium metaphosphate but not the hydrolysis of sodium pyrophosphate. One alkaline phosphatase found in the fixed plant tissues specifically hydrolyzed guanylic acid but no other nucleotide and one specifically hydrolyzed metaphosphate to orthophosphate. The enzymes in both plant and animal cells which hydrolyzed metaphosphates and pyrophosphates were found to require magnesium ions for their activity and to be inhibited by fluoride ions. "Alkaline phosphatase," so intimately associated with the chromatin in the nucleus, is postulated to be not just one enzyme but a number of enzymes.

BOOK REVIEWS

PUNCHED CARDS, by Robert S. Casey and James W. Perry. 506 pages, illustrations, 16 × 24 cm. New York, Reinhold Publishing Corp., 1951. Price, $10.00.

The punched card is a tool which has found wide acceptance in the fields of commerce and scientific endeavor. Not only is it widely used in commercial accounting and statistics but also for processing many kinds of scientific data. Once the data are coded and punched on the card, a wide variety of operations can be performed, for example: sorting; rearranging the cards in any required sequence; and the arithmetical operations of addition, subtraction, multiplication, and division. Hand sorting methods can be used in the first two examples, whereas machine methods can be employed to perform all of the tasks mentioned previously.

The use of punched cards facilitates many routine and repetitive operations involving the solution of certain problems, particularly problems in which large masses of data are involved. They are a labor saving device. Often times, tasks are performed at a relatively low cost, using punch card techniques, which could not otherwise be considered by other methods due to their prohibitive costs.

One of the authors' objectives has been to advocate the use of punched cards by members of the technological fields in the solution of many of their problems. Notable among the examples of this type of card usage is that of file searching, which can become unwieldy even in the case of the most modest files. Many different uses of the cards are depicted in a wide variety of industries, which may serve as a stimulus for further development.

The volume is divided into five different sections which deal with all the aspects of punched cards. Part One serves as an introduction to the subject, and it is also a handbook on the hand-sorting method. Case histories of punched card applications are covered in the second section. This second section is the most important, in that the varied nature of the tasks which can be performed by punched cards are expounded here. The third section deals with the general and fundamental considerations. The fourth section is a study as to the role that punched cards and related devices may eventually play in relationship to other methods for coping with information problems. Section five is a bibliography on the uses of punched cards. Throughout the greater portion of the book emphasis is placed on the handsorting methods rather than on the machine methods.

This book is particularly well suited to anyone confronted with the problem of handling great masses of information. The varied uses of punched cards as brought out in this volume are thought-provoking to anyone seeking a practical, novel treatment of a perplexing problem.

T. J. BOWDEN

BACTERIOLOGY, by Robert E. Buchanan and Estelle D. Buchanan. Fifth edition, 678 pages, illustrations, 15 × 22 cm. New York, The Macmillan Co., 1951. Price, $6.00.

This text should be fully adequate for a first course in microbiology. The emphasis is on morphology, classification, biochemical reactions, and economic importance of microorganisms. There is also a portion of the book devoted to the organisms pathogenic for animals and plants. The discussions of the importance of microorganisms in the fields of agriculture, industry, and food processing are well done and should be of practical value to the student.

The chief criticism of the book is the lack of reference material for the student interested in exploring further any of the subjects covered. Another criticism is that the chapter on immunology and serology is very much out-of-date and should definitely be revised in the light of newer information about such subjects as the site of antibody formation, the nature of antigens and antibodies, and allergic reactions.

WARREN R. STINEBRING

THE NATURE OF THINGS, by Roy K. Marshall. 188 pages, diagrams, 15 × 22 cm. New York, Henry Holt and Co., Inc., 1951. Price, $2.95.

Dr. Roy K. Marshall, a former director of the Fels Planetarium, has acquired for himself a large and faithful television audience for his popular presentation of science. He has made a selection from the talks given to this audience and offers them to the reading public. The publication of these talks raises the interesting question: which is the more effective form of presentation, the printed book or the television screen? There can be no question about which offers the greater audience. The television viewer pays no fee to see and hear Dr. Marshall, has the advantage of witnessing his personality at work (and few television artists, or artistes, know better how to display a personality), and can see the demonstrations he performs. The reader has to get along without benefit of the wink and the nudge, since neither can be reproduced typographically; and line drawings by Jon Gnagy replace the demonstrations. The reader has the advantage of enjoying the material as and when he wants it, he can refer to it after the video screen has gone dark, and he will have the ability to follow up the lesson with the next, while the viewer has to wait a week and hope that he has not forgotten what went before.

Dr. Marshall has the unique faculty of making involved subjects sound simple by translating them into language which everyone can understand. By this means he has enabled his large audience to grasp the elementary principles of atomic structure, nuclear fission, relativity, and the galactic universe. His touch is light, his similes apt, and the book forms an excellent introduction to science for anyone who does not wish to probe too deeply into complexities nor to cultivate a technical vocabulary.

T. C.

THEORY OF PERFECTLY PLASTIC SOLIDS, by William Prager and Philip G. Hodge, Jr. 264 pages, diagrams, 15 × 24 cm. New York, John Wiley & Sons, Inc., 1951. Price, $5.50.

One of the foremost investigators in the field of plasticity gives us a connected account of the at-present established theory of perfectly plastic solids. Professor Prager and his co-worker, Professor Hodge, are probably the best qualified men to give a unified and homogeneous treatment of this division of the theory of plasticity.

The classical theory of elasticity was complete in all essentials long before the turn of the century. After Saint Venant established the foundations of the mathematical theory of plasticity in 1870, not many investigators were attracted by the subject until after 1920 when a number of brilliant men—v. Karman, v. Mises, Nadai, Prandtl, Hencky, Reuss and Hill—developed the mathematical theory of plasticity.

The theories considered by the authors are: the Saint Venant-Levy-Mises theory based upon the consideration of plastic strains and neglecting the elastic strains, and the theory of Prandtl-Reuss, taking into account elastic as well as plastic strains.

Of the utmost importance in practice is the range of contained plastic flow and of unrestricted plastic flow in technological forming processes such as rolling, drawing and extruding. The theory of work-hardening plastic solids has as yet not reached a definitive stage and has not been included by the authors.

The introduction describes the mechanical behavior of a perfectly plastic material, a far-reaching idealization of the actual behavior of typical structural metals. The basic concepts are discussed in chapter one, while the second chapter deals with the elastic-plastic behavior of trusses and the flexure of beams of rectangular cross section.

Torsion of cylindrical and prismatic bars is taken up in chapter three with a full discussion of plastic stress distribution, warping of cross sections and the combined torsion and tension of a circular cylinder. Chapter four applies the Prandtl-Reuss theory to the problem of a thick-walled circular tube under varying internal pressure to obtain the elastic-plastic behavior.

An exposition of a general theory of plane elastic-plastic strain is contained in chapter five. Excluding bodies of symmetrical forms, the elastic-plastic boundary is *a priori* not known and no general methods of solving such problems have been developed so far. There-

fore, unrestricted plastic flow is the principal topic treated in detail. Specific problems in plane strain are taken up in chapter six, including the problem of incipient plastic flow and the behavior of materials in steady plastic flow, typical examples of which are the processes of rolling, drawing, machining and extrusion of structural metals.

Chapter seven is principally concerned with the phenomena of contained plastic deformation. It contains a discussion of the plate analogy, a device which was first suggested by Prager to help the investigator form a qualitative picture of the elastic-plastic stress distribution and of the shape of the elastic-plastic boundary. The safety factor of an elastic-plastic body in plane strain is defined and theorems are given which give lower and upper limits for the safety factor. An analysis of the two theories establishes the fact that the Prandtl-Reuss theory must be used in the treatment of problems of contained plastic deformation while the Mises theory is generally accepted as adequate for the treatment of problems of unrestricted plastic flow.

The reader will find the final chapter most difficult and the serious student will probably find it the most inspiring. The Cartesian tensor notation is introduced prior to a consideration of extremum principles. For a body which obeys the stress-strain laws of Mises, the extremum principles of Hill and Markoff are established. In the case of the Prandtl-Reuss theory, the theorems due to Greenberg are demonstrated. So far little use has been made of the extremum principles owing to the inherent difficulties in this type of analysis.

This volume is the definitive introduction to the mathematical theory of plasticity, an excellent exposition of the methods of investigation, and an account of what has been accomplished.

R. FRIESINGER

ARCHITECTURAL GRAPHIC STANDARDS, by Charles George Ramsey and Harold Reeve Sleeper. Fourth edition, 614 pages, illustrations, 24 × 30 cm. New York, John Wiley & Sons, Inc., 1951. Price, $10.00.

First published in 1932, this book quickly established itself as a standard reference work for draftsmen, decorators and builders, but more particularly for architects and engineers. The second and third editions followed in close order—1936 and 1942—and in these the organization was improved and the scope greatly increased. In the nine years between the third and fourth editions, great strides have been made in building techniques and a multitude of new materials and new methods have proven themselves. The fourth edition was long overdue, but this reviewer believes it well worth waiting for.

The authors might well have been content to add the new material to the prior work and this alone would have been a tremendous task, for 368 new plates have been added. In this alone they have, however, not been content, for of the 197 plates they had to start with, 151 were revised and only 46 reappear unchanged.

Since your reviewer cannot qualify for any of the professions for whom this book is designed, but can only come in under the heading ". . . others interested in building," he cannot definitely state that all new material that should have been included has been, but he can say that all he is familiar with, he looked for and found.

The index of over 11,000 items is excellent and if any criticism is to be made, it is that it may have been overdone. "Knives, kitchen" or "Kitchen equipment & appliances" should have sufficed, while "grapefruit knife" (together with 9 others) is redundant, especially since they are all on page 413. Many other examples of over-indexing could be cited, but won't be, for it is more important to say that the indexing could not be found underdone in any respect—the cross-indexing is excellent.

Those who are using *Architectural Graphic Standards* in past editions are well advised to retire them, probably well worn anyway, for the fourth edition is so improved it will be many times more valuable to them.

JOHN MOORE

BASIC WING AND AIRFOIL THEORY, by Alan Pope. 294 pages, illustrations, diagrams, 16 × 24 cm. New York, McGraw-Hill Book Co., Inc., 1951. Price, $5.00.

Professor Pope's past and present style and well-integrated presentations are placing him amongst the foremost writers of the aerodynamic profession. Utilizing his extensive teaching and research experience, once again he ably fills the usual gaps between elementary and advanced theory. This is always an extremely difficult task, too often sorely neglected by others. The material presented in this book is amazingly up-to-date considering the usual dead time between preparation and publication and the many new theories and research findings in this fast-moving field. Noteworthy also are the many judiciously arranged illustrations and illustrative examples, giving the reader a more effective grasp of the contents.

This book was prepared primarily as a text for the college senior or first-year graduate student level and has been used in mimeograph form at the Georgia Institute of Technology in a one-year course since 1941. If less concentration is placed on derivations and more attention paid to application, the course can be shortened appreciably. In order to familiarize the less advanced reader with some of the more advanced mathematical tools necessary in this field of endeavor, the first two chapters have been included to equip him with the necessary knowledge of vector analysis and complex variables. A total of 13 chapters is presented. Chapter 3 deals with the stream function and is followed by chapters on other flow functions, the Jonkowski transformation, airfoil construction and pressure distribution, thin-airfoil theory, thick-airfoil theories, the finite wing, the monoplane wing, the field about the wing, spanwise load distribution for arbitrary wings, and miscellaneous applications of perfect fluid theory. Each theory is clearly followed by a statement of its limitations along with its applicability in up-to-date practice.

S. M. BERKOWITZ

MAGNETIC MATERIALS, by F. Brailsford. 156 pages, diagrams, 11 × 17 cm. London, Methuen & Co., Ltd., 1951; distributed in U. S. by John Wiley & Sons, Inc. Price, $1.50.

This pocket-sized volume is a second edition of an earlier "Methuen's Monographs on Physical Sciences" by the same author. There has been no extensive revision of textual material; however, the subject matter has been extended by the addition of a number of recent references.

For so brief a volume, fairly comprehensive discussions are given for the following: introductory ferromagnetic theory, magnetism in single crystals, factors affecting magnetic materials, magnetism in various iron alloys and permanent magnets.

The book is not intended for use as a text or as an extensive reference work; however, the language and notation are clear and not too technical so that it can well serve as an introduction to ferromagnetism for the student or technologist.

ERIK KLOKHOLM

200 MILES UP, by J. Gordon Vaeth. 207 pages, illustrations, 15 × 24 cm. New York, The Ronald Press Co., 1951. Price, $4.50.

For those interested in the background and present state of high altitude exploration and research, presented in non-technical and very readable form, *200 Miles Up* will prove very interesting and enjoyable reading.

Mr. Vaeth seems to have the ability to describe the complex equipment used in upper air exploration in simple terms which will be understandable to the average reader, including sections on cosmic radiation and spectrography.

He describes the vehicles used to elevate the measuring equipment into the stratosphere and ionosphere—the balloons and rockets, the principles involved and the mechanical equipment—with a chapter on "How the V-2 is Fired," and chapters on the latest research vehicles, the Aerobee and the Viking.

It is a well illustrated, interesting and informative book.

R. S. BARNABY

BOOK NOTES

BEET-SUGAR TECHNOLOGY, by R. A. McGinnis, ed. 574 pages, illustrations, tables, 16 × 24 cm. New York, Reinhold Publishing Corp., 1951. Price, $10.00.

This is a comprehensive, practical reference book covering the manufacture of beet sugar in the U. S. and foreign countries. In the attempt to cover the field, brief elementary discussions have been given on all phases of the industry. The history, culture, insect pests, plant diseases, the tare laboratory, beet storage, diffusion, chemistry of beet sugar including processes of purification, crystallization, saccharate processes, and drying have been given more thorough discussions. The book is designed to serve as a reference book for both the technical and professional worker in the beet-sugar industry.

STATISTICAL METHODOLOGY REVIEWS 1941–1950, by Oscar Krisen Buros, ed. 457 pages, 19 × 27 cm. New York, John Wiley & Sons, Inc., 1951. Price, $7.00.

This volume is the third in a series of publications prepared to assist research workers and statisticians to locate and to evaluate the statistical methodology books in all fields using statistical methods. Only books on statistical methods and closely related subjects are listed, and only those books of value have been included. A total of three hundred and forty-two books written in English and published or reviewed in the ten-year period 1941–1950 are listed. Two sets of numbers are used—page numbers and entry numbers; there is a roughly classified subject index; book entries in section "Books and Reviews" are arranged in alphabetical order by journals, with a key to abbreviations used for excerpted journals; and a publisher directory and index, an index to titles, and an index of names (authors and reviewers, etc.,) are included to aid the reader.

GENERAL CHEMISTRY, by William A. Felsing and George W. Watt. Third edition, 558 pages, illustrations, 16 × 24 cm. New York, McGraw-Hill Book Co., Inc., 1951. Price, $5.00.

The subject material in the third edition has been revised and reorganized to aid the student in the understanding of the subject. Atomic structure is presented before periodic arrangement of the elements, treatment of combining weights has been simplified, equivalent weights is given special emphasis, and oxidation-reduction reactions and nuclear chemistry modified. A variety of exercises and problems is included.

LABORATORY EXPERIMENTS IN GENERAL CHEMISTRY AND QUALITATIVE ANALYSIS, by George W. Watt. 227 pages, diagrams, 25 × 29 cm. New York, McGraw-Hill Book Co., Inc., 1951. Price, $2.75.

The laboratory manual is designed to be used in conjunction with *General Chemistry* (see above), but may be adapted for use with other textbooks. The manual is stream-lined, giving only directions necessary for the conduct of the experiments, labeled diagrams are used for assembling of apparatus, and work sheets are included for all experiments.

INTEGRAL TRANSFORMS IN MATHEMATICAL PHYSICS, by C. J. Tranter. 118 pages, 11 × 17 cm. London, Methuen & Co., Ltd., 1951; distributed in U. S. by John Wiley & Sons, Inc. Price, $1.50.

The monograph outlines a procedure to be followed in using an integral transform in the solution of boundary-value problems. It proposes to show that a similar technique can be employed whatever the kernel or range of the integration of the transform. The author claims the method is more direct and straightforward than the classical method. The method may be adequate for some investigations in mathematical physics, but assumptions have to be made, and other limiting factors have to be considered.

THE CLIMATE NEAR THE GROUND, by Rudolf Geiger, translated by Milroy N. Stewart and others. 482 pages, illustrations and diagrams, 14 × 22 cm. Cambridge, Harvard Univ. Press, 1950. Price, $5.00.

Microclimatology or what has been described as "Climate in the Least Space" is a relatively new science. It is recognized as a natural outgrowth of climatological investigations which are of direct significance to man.

We have difficulty in recognizing that the air layer which directly affects us and is therefore five or six feet above the surface of the ground is different from the air layer which lies directly on the surface. This book makes a sharp distinction between the two climates and deals only with that portion of the climate which extends from the surface to a height of about five feet.

The surface of the earth plays a more important role in meteorology than is commonly understood. The atmospheric temperature through the course of a day and according to the season is directly influenced by the surface. This influence acts as a brake to winds, it acts as a reservoir for water and as a well for heat or cold. By the use of plants its effects are felt not only on vertical scale, but the horizontal contrast is present. It has been established that great climatic differences can result from various types of surfaces.

"The Climate Near the Ground" has provided an excellent introduction and a first survey of microclimatological problems.

THE FRANKLIN INSTITUTE

exists today because of the faith and generosity of the men and women who for 127 years have given time and money to its support.

The Institute welcomes financial gifts and bequests and hopes that all those who desire to perpetuate its work will make the The Institute one of their beneficiaries.

FORM OF BEQUEST

*I give and bequeath to The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, the sum of*_____

CURRENT TOPICS

Microscope for Radioactive Materials.—Deadly radioactive materials, hidden behind a thick concrete wall, can now be safely studied and photographed under a microscope by atomic scientists, using a new instrument jointly announced by American Optical Company's Instrument Division, at Buffalo, N. Y., who built the device, and the General Electric Company.

First of its kind, the instrument is being installed in the Knolls Atomic Power Laboratory, operated at Schenectady by General Electric for the Atomic Energy Commission. According to Dr. Kenneth H. Kingdon, technical manager of the laboratory's technical department, it is expected to make possible investigations that have never before been accomplished on the effects of radiation damage to materials.

The instrument is a special microscope for examining the structure of metals, combined with camera, periscopes and an illuminating system, in such an arrangement that light can get in and out through the thick walls of the test chamber, but nuclear radiations from the radioactive specimens are completely blocked.

Operated by remote control, the instrument permits atomic researchers to work in complete safety. Some sort of remotely controlled "mechanical hands," similar to those developed by KAPL engineers and first announced in 1948, could be used to place the specimens in position, and to remove them after examination.

Original schematic designs and specifications for the microscope were developed by Col. H. H. Zornig, of the KAPL staff. Scientists and engineers of the American Optical Co., under the direction of Joseph D. Reardon, put the instrument into practical form.

Light for illumination of the specimen comes from an arc lamp outside the thick-walled test chamber, and goes into the chamber through a lens system placed in a tubular hole through the wall. The light is reflected from the specimen, and comes out again through another series of lenses, to form the magnified image.

Both lens systems are offset by means of mirrors, which change the light path from horizontal to vertical, and then back to horizontal again. Radiations from inside the test cell are not reflected, and cannot get around the offset. If the tube were straight, however, they might be able to emerge through the opening for the lenses.

In using the microscope, which extends into the test chamber, the specimen is put into place on the microscope stage. Looking through a single eyepiece, the operator employs the remote controls to get the specimen adjusted and properly focused. Then the visual eyepiece is exchanged for a photographic one, and the camera is swung into position to make the photograph.

At the lowest power, the instrument shows the specimen in its actual size, without any magnification, whereas 1000 diameters magnification may be obtained with the highest power. These different powers are achieved by the use of several objective lenses for the microscope, which are mounted on a revolving turret and can be swung into place, again by remote control, as

desired. The objectives are so adjusted that it is not necessary to refocus when changing from one power to another.

Polarized light, consisting of vibrations in a single plane, as opposed to ordinary light in which the vibrations are in many different directions, is invaluable in the study of metals, and may also be used. This is made possible by a light-polarizing slide in the path of light from the illuminator. By remote control the slide may be put in or out of position as desired.

Voltage Variation in Radio Frequency Induction Heating.—Line voltage variations and shortened tube life are no longer deterrents to wirespread industrial use of radio frequency induction heating equipment.

According to J. G. Sola, president of the Sola Electric Company, Chicago, total RF heating units installed in American factories now have an operating capacity in excess of 500,000 kilowatts, representing an investment of more than 75 million dollars. He pointed out that more than 55 per cent of this capacity has been installed within the last ten years, although RF heating equipment has been commercially available since the early 1920's.

Sola credits significant design advances in RF units—including improved vacuum tubes and provision for built-in voltage control—as factors responsible for its rapid acceptance during the past decade.

An executive of Lindberg Engineering Co., Chicago, a leading manufacturer of a wide variety of industrial heating equipment, points out that theoretical advantages of RF induction heating over conventional equipment, for specific manufacturing operations, have long been known. According to F. A. Hansen, Lindberg's vice president in charge of engineering, RF permits fast, accurate heating of ferrous and non-ferrous metals by placing them in an alternating magnetic field. This permits heat application exactly at the area desired, and the amount of heat or power concentration per unit area is very much greater than that obtainable by any other method. Greatly reduced heating time and simplicity of control—unskilled labor can operate the units—are further advantages.

But, until comparatively recently, initial and maintenance costs of RF heating were high, Hansen said. Since such units are basically radio transmitters, early equipment was built around broadcast service type vacuum tubes which were not completely engineered for heavy-duty, round-the-clock industrial use. Outside line voltage variations of as little as 10 or 12 per cent could shorten the life of these tubes by as much as 65 per cent. Replacements, which were costly, could be frequent.

Production bottlenecks during World War II concentrated research on RF potentials. Industrial heating engineers knew that many operations could be performed more quickly and economically by selective radio-frequency heating, provided maintenance costs did not cancel out this advantage. Many industrial heating equipment manufacturers went to work on the problems, and the design changes their engineers effected provided the solution.

At Lindberg Engineering Co., for example, the voltage variation difficulty was solved by built-in constant voltage transformers manufactured by Sola. The Sola transformers are an integral part of each Lindberg unit and insure normal life of the rectifier and oscillator tubes. The tube itself is no longer the broadcast service type, but a sturdy, heavy duty tube, ranging in power

from 5 to 50 kilowatts and keyed specifically to modern industrial requirements. Since the tube's filament is protected at all times by a constant voltage source, one of the principle limitations of pre-war equipment is automatically eliminated. Improvements in cabinet designs, water cooling and quenching systems, and elimination of all internal rubber hosing are additional features of modern, post-war RF units.

As a result of the research and resourcefulness of American manufacturers, radio frequency induction heating is now a permanent part of the nation's industrial scene. Such uses as selective hardening, high temperature brazing, soft soldering, and selective annealing are now only a few of the many applications made economically possible by the improved new units. Important among numerous additional uses are heating for shrink fitting, melting electrolytically deposited tin for tin reflow, and melting small amounts of ferrous, non-ferrous and precious metals.

RF heating is now not only supplementing conventional furnace heating, but replacing other heat applying methods in a wide variety of manufacturing operations.

Electron Sterilization.—Blood plasma, for the treatment of military casualties as well as civilians, might be sterilized with high-energy electron rays more efficiently that with methods now employed, according to a General Electric scientist.

Speaking before a meeting of the Fourth District Branch of the Medical Society of the State of New York, at the G.E. Research Laboratory, Dr. Ernest E. Charlton cited blood plasma as one of many materials on which electron or cathode ray sterilization might be used effectively.

The great advantage of cathode rays in killing germs and molds, he said, is that such sterilization may be accomplished without heating the material. This is particularly attractive, he pointed out, for certain drugs, and other products, that might be damaged by heating.

As for blood plasma, he said that ultraviolet rays are now employed for sterilization. While these rays do not heat the plasma, they do not penetrate into it as deeply as would the high-voltage cathode rays. Thus sterilization with electrons might be more efficient.

Further laboratory work is needed in order to make sure that cathode-ray treatment of blood plasma does not cause the formation of any poisonous compounds, he continued.

Dr. Charlton, who heads the laboratory's X-ray Section, said that the application of high-energy electrons in the field of food sterilization also has far-reaching potentialities. In laboratory experiments, meat, fresh beans, grains, blueberries, strawberries, peaches, raisins, bread and honey have been sterilized in this way.

"Wrapped bread that has been exposed to the cathode rays has been kept for many months at room temperature without becoming moldy and has retained a fresh bread odor," he said. "Even sterilization of the surface of some foodstuffs may have far-reaching implications. By extending, even for a few days, the time that perishable foodstuffs can be stored, or transported, without reduction in quality, the economics and utilization of these products can be vastly changed," he said.

In order to get adequate penetration of the rays, needed to sterilize such items as glass vials containing antibiotics and other drugs, it seems entirely feasible to build a cathode-ray generator operating at from five million to ten million volts energy, he said.

The generator now being used in the G–E Research Laboratory operates at about 900,000 volts. It is a modified G–E million-volt X-ray machine. X-rays are generated when a beam of electrons hits a tungsten target. In the generator of cathode rays a thin metal window takes the place of the target and the electron stream is able to emerge into the open air, where it can be aimed at the materials to be treated.

"Magic Marker."—A new medium promises to solve many marking problems in Industry, Business, Art, Sports and the Home. Known as "Magic Marker," it is a throw-away-bottle marking unit with an ability to write on a greater variety of surfaces than has ever been possible with one device before. It writes with a felt tip which is cleverly designed to permit fine, medium and bold one-stroke marking. When the ink supply is finally exhausted, the longlasting nib section is unscrewed from the bottle and attached to a fresh refill.

The new Speedry ink used in "Magic Marker" includes all of the features pioneered and developed by its manufacturer, Speedry Products, Inc., New York, since it made the first instant-dry ink for industrial marking purposes. To point out the significance of the new "Magic Marker" ink, it should be noted that Speedry marking inks are made in a range of types for almost all known needs, both specific and general. Individual types include such properties as being instant-dry, waterproof, sunfast, opaque and translucent, launderproof and so on. Some inks are for porous surfaces, (paper, wood, leather, textiles), others for nonporous materials, (metal, glass, china, plastics). It is made in nine colors including black and white.

"Magic Marker" will prove a valuable, as well as handy, aid in hundreds of ways. It is ideal for addressing and marking shipments, factory production and inventory-marking, office color systems. The merchant can make his own professional-looking price cards and signs, the housekeeper and home-owner now have an easy way to label jars, storage packages, plumbing and wiring continuity, garden tools and markers. In art and science, sports and hobby-crafts, marking on as many surfaces as man or nature has created is now as simple as lifting the cap on "Magic Marker."

Incidentally, the "Magic Marker," is spillproof since it has no loose ink. It is made on the exclusive Speedry principle "Capac" or "Capillary Action," in which all the ink is held within a felt-pack in the bottle. Control of the ink to the writing nib is automatic, too, through special felt density-control.

Life Span Increased Through Chemistry.—The "fountain of youth," elixir of eternal life, is slowly approaching reality.

Twenty centuries ago, the alchemists sought the answer to immortality at a time when the average life span was only 22 years. Today, the average human has tripled that life expectancy to 67 years, according to John L. Davenport, executive vice president of Chas. Pfizer & Co., Brooklyn, N. Y., producer of antibiotic drugs.

Mr. Davenport, who spoke on the General Electric Science Forum program over WGY, praised the chemists of this country, who recently celebrated the 75th anniversary of the American Chemical Society, for their unending contributions to the extension and preservation of human life.

"The past ten years have been aptly called the decade of antibiotics," he said. "The era began with penicillin, which has proved effective in 25 different diseases, and has culminated in antibiotics such as terramycin, which are capable of curing more than 50 infections."

The chemists' work has developed many new synthetic vitamins and hormones, as well as antibiotics, at a tremendous price in money, time, and energy. "For example," said Mr. Davenport, "before terramycin was discovered, 100,000 soil samples were collected from every corner of the world, and each sample was studied separately. The entire process covered a period of two and one-half years, and at a cost of four million dollars."

The new group of antibiotics has had a remarkable effect upon the operation of the medical profession. The number of beds needed for infectious cases has been radically reduced; doctors now can treat approximately 50 per cent of their patients with antibiotics only; mastoid is almost extinct; pneumonia is no longer to be feared; and childhood diseases are very easy to control.

"But the search is not over. Cancer, polio, and the common cold have eluded control, although a tremendous effort is being made to find vaccines and antibiotics to curb the three diseases," he said.

"While human life has been extended enormously during the 20th century, other problems have arisen. Infectious diseases are rapidly declining as the cause of death, but as our population becomes older, the degenerative diseases of the heart and other internal organs begin to increase. A new science—geriatrics—has been developed to seek techniques for assuring older people health and happiness."

Decontaminating Solution.—Radiacwash is the first commercial general purpose decontaminating solution specifically created to remove radioactivity from contaminated surfaces, it is claimed by its manufacturers, Atomlab, Inc., of New York City.

Radiacwash is a concentrated solution designed for rapid use in emergencies. It has a long shelf-life and is effective with hard, soft or salt water. Combining several physical and chemical principles of decontamination, the liquid acts as a combination detergent, emulsifier, solvent, ion-extractor, surface wetter and carrier.

Radiacwash can be diluted to fit specific decontamination applications in the cleaning of laboratory instruments and equipment, cloth, glass, metal, and other materials. A dilution of 5 parts water and 1 part Radiacwash has proven both effective and safe for the hands and other skin surfaces. It contains an antiseptic to afford extra protection for personnel who may have open cuts or burns.

The effectiveness of the solution on individual atoms is not influenced by the level of radioactivity, since Radiacwash "lifts-up" contaminants by physical and chemical action.

While Radiacwash has not been tested in the wake of an atomic attack, its manufacturers say that it has worked successfully on the type of contaminants likely to be found after an atomic catastrophe.

Chloromycetin Custard for Children.—A new Chloromycetin product, which tastes like custard, has been developed by Parke, Davis & Company for the thousands of children too young to swallow the life-saving antibiotic in capsules. The new product is called Pediatric Chloromycetin Palmitate.

Since crystalline Chloromycetin is bitter, it has been administered chiefly in capsule form. The creamy new product for children has a rich custard flavor, and actually contains a tasteless derivative of the antibiotic. This new chemical offspring was discovered only after hundreds of experiments were completed in the Parke-Davis laboratories. Palmitates are common substances present in many everyday foods.

Graydon L. Walker, director of U. S. and Canadian sales, said, "Because of heavy demands for all Chloromycetin products, Pediatric Chloromycetin Palmitate will not be in plentiful supply at the outset." He added that production will be increased as rapidly as possible.

Pediatric Chloromycetin Palmitate will be useful in treating many bacterial and rickettsial infections, including whooping cough, measles, mumps, enteric fever, dysentery, typhoid fever, undulant fever, primary atypical pheumonia, urinary tract infections and the like.

An important consideration for busy mothers is that Pediatric Chloromycetin Palmitate does not require refrigeration. As in the case of other forms of the antibiotic, the children's product is available only upon the prescription of a physician.

Television Tests on Ultra-High Frequency.—Some of the results of test transmissions of television signals using an ultra-high frequency of 850 megacycles were outlined here recently by Dr. George H. Brown, of RCA Laboratories, Princeton, N. J., before a meeting of the Professional Group on Broadcast Transmission Systems of the Institute of Radio Engineers, at The Franklin Institute. The tests were carried out at station KC2XAK, at Stratford, Conn. KC2XAK has been operated experimentally since January 1, 1950, by RCA and NBC for the study of UHF transmission and reception. Previous tests were made on a frequency of 530 megacycles.

The recent experiments, Dr. Brown said, also involved the use of a special antenna which could be tilted to change the direction of the signal beam. By tilting the beam downward, he reported, the strength of the 850-mc. signal through the adjacent Bridgeport area was increased approximately three times over the signal supplied by the antenna in its normal position.

Further tests, Dr. Brown announced, will be conducted with the tilted antenna to determine its effectiveness in extending the program service of television stations operating on UHF.

Portable Radiation Probe.—A new lightweight radiation probe, for detecting and measuring alpha, beta, gamma, and neutron radiations, has been announced by General Electric's Special Products Division.

Developed at G.E.'s General Engineering Laboratory, the probe is designed for use in hospitals, and industrial and university laboratories where work with radioactive materials is being conducted. It will have application in monitoring contamination of clothing, personnel, laboratory equipment, and facilities.

The scintillation counter, which has all the usual advantages of such an

instrument, includes a phosphor, photomultiplier tube, and a two-stage amplifier with low-impedence output. Light flashes, produced when nuclear particles strike the phosphor, are converted into electrical pulses by the photomultiplier. This allows radiation detection and measurement under even the most difficult circumstances. Alpha particles, for example, can be counted even in the presence of high beta-gamma backgrounds.

The phosphors for detecting alpha, beta, gamma, and neutron radiations are incorporated into specially designed caps placed on the end of the probe. These detecting heads can be quickly interchanged and the various phosphors in the caps are easily replaced should the need arise.

The neutron cap alone, adapted to measure beams of thermal neutrons, is expected to have wide application in general health physics work.

The complete detector is $2\frac{3}{8}$ in. in diameter, 15 in. long, and weighs approximately 10 lb.

Three-Dimensional Motion Pictures Perfected (adapted from *Technical Data Digest*, Vol. 16, No. 9).—An improved process for presenting three-dimensional motion pictures in color has been developed by the Instrumentation and Analysis Section of the Technical Photographic Service Section, Materiel Division, Wright Air Development Center, Dayton, Ohio. Using the alternate frame technique, the process uses one camera, one reel of film, and one projector.

Major R. V. Bernier, who developed the method, said it became possible when he perfected a barrel-shaped polarizer that revolves in front of the projector's lens. This selectively diverts the right eye pictures on the film to the right eye only, and the left eye pictures to the left eye only—a strict requirement of three-dimensional vision.

When the film is shown, viewers wear polarized spectacles that allow the left and the right eye to see alternately every other frame projected on the screen. The result is a synthetic true vision.

The projection requirements for alternate frame film are substantially the same as for other three-dimensional systems. The right and left eye images must be registered properly on the screen, and must be selectively polarized for their respective eyes. It has been the practice to use the same type of attachment on the projector that was used on the camera. Such an attachment, a beam splitter with synchronized shutter, was tested prior to the development of the present adapter, which resulted from an attempt to eliminate the screen registration problems characteristic of the beam splitter arrangement.

In the opinion of Major Bernier, 35-mm., three-dimensional entertainment film could be produced today. A relatively simple modification could be made to present theater projectors to accommodate a special optical-mechanical attachment designed to eliminate flicker, as well as to selectively polarize alternate full frames. This attachment, on which additional patents have been filed, will eliminate the need for any mechanical alterations to the film transport mechanism.

A color film, "Three-D Motion Pictures," has been produced for the Air Force by Major Bernier and his assistant, M/Sgt. J. C. Blotner, to serve as an educational medium in the use and application of the new method. Three-

dimensional, high-speed movies have been made at the Wright-Patterson Air Force Base showing the action of such things as rapid-firing weapons on aircraft, flying missiles, and missile impact tests. Time-lapse movies have been made, depicting in three dimensions the life cycle of living things, and shortening them to a few seconds on the screen.

Skin in Three Dimensions (*General Electric News Digest*, Sept.-Oct., 1951).—A new defense production tool, capable of producing jet aircraft "skin" structures lighter yet stronger than ever before possible, has been developed by engineers of the Giddings and Lewis Company, General Electric, and the Lockheed Aircraft Corporation. It is thought to be the world's first machine for the manufacture of self-reinforced aircraft skin.

The giant, 80-ft.-long machine, electronically controlled by G.E. equipment, automatically cuts, edges, and shapes a particular pattern in three dimensions in one surface of a metal sheet. A two-dimensional electronic tracer control, developed by G.E., causes the machining equipment to cut a pattern laterally and longitudinally according to a master pattern, while a cutting device known as a vertical milling head cuts the surface to varying thicknesses.

The new type of skin structure will eliminate the necessity of welding or riveting into the plane the customary forest of struts, braces, and girders. Instead, fewer and simpler strengthening units will be used as integral parts of the skins, allowing new planes to be stronger, lighter and faster.

The machine will be used in Lockheed's new $5,000,000 *Hall of Giants* fabricating plant in Burbank, California, in the production of new F-94 jet fighters.

The lub-oil goes round and round in AF engines, and some of it is the same old oil, re-refined in Air Force efforts to conserve natural resources. During fiscal-51, over 1,500,000 gallons of used engine oil were recovered and processed, yielding 1,115,000 gallons of re-refined oil as well as a substantial financial savings. AF estimates that for every 1000 gallons of new oil issued, 250 gallons of used oil will be accumulated, 177 gallons of re-fined oil will be recovered; plans now include re-refining of used oil from ground equipment.

Thermos boots for the Marines in Korea have been tested at 45 degrees below zero, should eliminate the frostbite which claimed so many victims in the wet-cold of last winter. Actual tests of the sealed insulation rubber boots, with water frozen in the boots and wearers donning frozen socks, showed that ice melted in 8 minutes and feet stayed warm thereafter. So long as a man moves once an hour to keep circulation normal, Marines say the new boots will prevent trench foot.

A new greaseless pack for rifles has been standardized by the Army Ordnance Corps, will soon replace the heavy, greasy preservative coatings long remembered by anyone who has had to unpack and clean a new rifle. The new pack consists of an outer layer of cotton scrim, a layer of plastic-coated aluminum foil, and an inner layer of kraft paper coated with a volatile chemical compound known as VCI or volatile corrosion inhibitor. Weapons are heat-sealed in the pack, VCI vapors form an invisible film which protects all metal surfaces against corrosion. Unpacking the weapon and putting it to use is expected to take not much longer than reading this paragraph.

Philadelphia Industries Represented in Advancement of Science Exhibits.—A large part of the credit for the rapid expansion and application of science during the past half-century should go to those who have provided the equipment with which the scientist works. An unusually varied collection of these tools and materials of science, including many produced by firms in the Philadelphia area, will be exhibited at the annual mid-winter meeting of the American Association for the Advancement of Science, to be held in Philadelphia the last week of December.

The Association, whose 18 sections and 225 affiliated societies make it the largest federation of scientific organizations in the world, was founded in Philadelphia in 1848, and this will be its seventh Philadelphia meeting. The scientific sessions, to be attended by about 10,000 research workers, industrial scientists, physicians, teachers and students, will run from December 26 to 31 and will be held in the Municipal Auditorium and in various hotels. The exhibits, organized as an Exposition of Science and Industry, will be open from December 27 to 30.

Occupying the main floor of the Auditorium, the 100 or more exhibits will range from books on antibiotics and atomic energy to such laboratory items as spectrographs, flask-shakers, plastic animal cages, radioactivity detectors and counters, ball-bearing microscopes and televised pond-life. Hundreds of devices and instruments that go into the outfitting of a laboratory or science teaching classroom will be displayed. And since most of the exhibits will be staffed by technical personnel, they offer those attending the meetings an excellent opportunity to learn the latest about the newest.

In the growing field of audio-visual education will be the exhibit of the RCA Victor Division of the Radio Corporation of America, Camden, N. J. This display will feature a new 16-mm. recorder-projector, by means of which the non-professional cameraman may give sound to his motion pictures. This is done by recording directly on a magnetic sound track built on the edge of the film. The equipment is expected to find wide use in the teaching of science subjects.

Biophysical Instruments, Inc., of Philadelphia, will exhibit a number of the highly specialized instruments it produces for research in biological, medical and industrial fields. Among these are a respiratory carbon dioxide sampler that measures the CO_2 in the last bit of breath expelled from the lungs during the breathing cycle, tiny thermocouples of hair-thin wire for making measurements of temperatures within arm and leg joints during the evaluation of new arthritis treatments, and X-ray accessories which permit unusually precise timing and rapid film-change.

A new style "Mouse House" of clear, transparent plastic with a perforated stainless steel roof will be displayed by the Keystone Plastics Company, of Swarthmore, Pa. The invention of Howard M. Fricke, head of the company, this laboratory animal cage is molded in one piece, like a rectangular glass baking dish, with smooth, rounded corners. Offering better visibility than a fishbowl, an advantage in research where frequent inspection of the animal is desired, the plastic houses are also vermin-proof and are easily cleaned. They can be sterilized with various chemicals, including one developed by the Keystone Company. The exhibit will include a variety of styles and sizes of the plastic cages, for rats, guinea pigs, hamsters, etc.

Other types of animal cages, as well as refrigerated boxes for shipping serums and human blood, and special equipment for blood-collecting centers will be exhibited by Harford Metal Products, Inc., of Aberdeen, Md. The most up-to-date methods of cultivating micro-organisms, preparing microscope slides and preserving and injecting microscopic specimens will be demonstrated at the booth of the Carolina Biological Supply Company of Elon College, North Carolina, and the Waubun Laboratories, of Schriever, Louisiana. A staff of professional biologists will be in charge of the latter booth to offer a complete biological materials information service. Among other exhibits of laboratory supplies will be that of the New Brunswick Scientific Company, of New Brunswick, N. J., which is featuring a new type of flask-shaker. This is of particular value in research on deep-culture production of antibiotics and in all types of fermentation work where vigorous aeration is desired.

Probably the most venerable of the AAAS exhibitors, only five years younger than the Association itself, is the 98-year-old Bausch & Lomb Company. It began business on November 3, 1853, as a small optical shop in Rochester, N. Y. It had a working capital of $60, a few supplies imported from Europe and the enterprise and skill of two young men named John J. Bausch and Henry Lomb. Their shop-window displays in the early days consisted of opera glasses, magnifiers and horn-rimmed eye-glasses. A few years later Bausch literally stumbled on the idea of making eye-glass frames of hard rubber, a piece of which he had found lying in the street.

With a steady income from "rubber-tired" spectacles, the company branched out in 1874 into the design and manufacture of microscopes, a field in which Busch's eldest son, Edward, excelled. At that time there were less than 100 microscopes in the United States. In the intervening three-quarters of a century, Bausch & Lomb has manufactured more than a half million of these instruments, the most recent models of which will be seen in the AAAS exposition.

Another pioneer to be presented in the Exposition of Science and Industry is the Socony-Vacuum Oil Company, which began as the Vacuum Oil Company in 1866. Its birthplace, like that of Bausch & Lomb, was Rochester, N. Y. The company began as an outgrowth of distillation experiments carried on by Hiram B. Everest, a grocer, and his friend, Matthew P. Ewing, a carpenter. They had a theory that by heating crude oil under vacuum they could increase the yield of kerosene, at that time the most valuable and marketable constituent of petroleum. Their theory didn't work, but the unburned residue in the still suggested possibilities as a lubricant, and it was this that started the business.

The exhibit of the Socony-Vacuum Laboratories, of Paulsboro, N. J., will include a glass-operating model of a modern Thermofor Catalytic cracking unit for manufacturing high octane gasoline. The operation will show the flow of catalyst and oil through the unit, although a non-inflammable liquid will be used in place of the oil, for the sake of safety. Devices for testing the mechanical and fuel behavior of automotive engines and for investigating lubricants and the principles of lubrication will also be demonstrated.

Adjacent to the exhibits will be a Science Theatre, with a program of 50 to 70 films for continuous showing, and the Annual International Photography-in-Science Salon.

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